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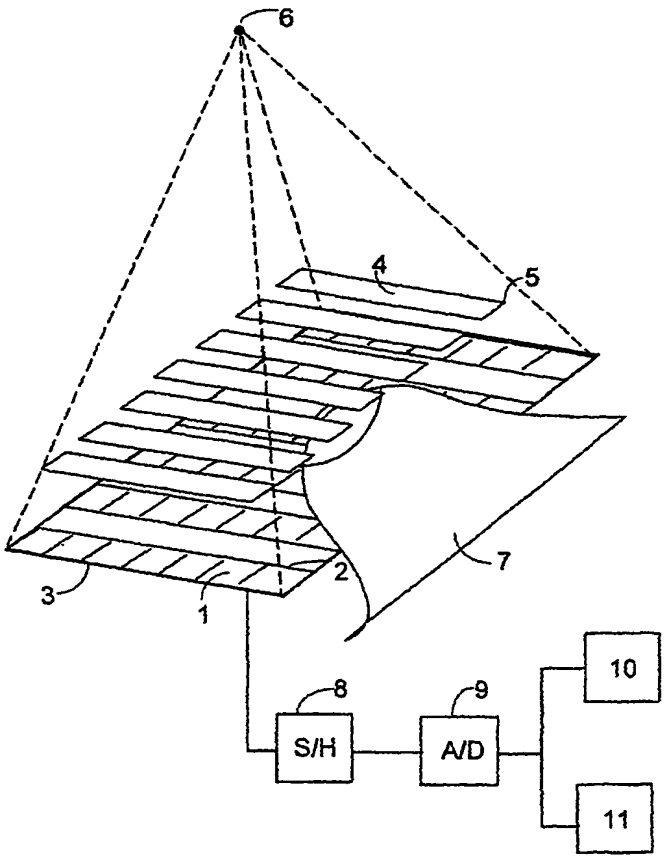

(57) Abstract: A digital imaging method, in which the object being imaged is irradiated and the radiation is detected by means of semiconductor sensors (1), covering an area which is smaller than the image-forming surface. The semiconductor sensors (1) are arranged in such a way that the image-forming surface can be imaged in two irradiations by moving the semiconductor sensors (1) between the irradiations. The radiation can be limited to the area covered by the sensors (1) by means of collimators (4). The semiconductor sensors (1) are arranged to form advantageously rectangular bars (2), which comprise several semiconductor sensors (1) in the form of one or two columns, in which the bars (2) are arranged advantageously at a distance from one another, the said distance between the bars being at most equal to the width of the active area of the semiconductor sensors of the bars.

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Method and apparatuses for digital imaging

The object of the invention is a digital imaging method, in which method the object being imaged is irradiated and the radiation is detected by means of semiconductor sensors covering an area which is substantially smaller than the image-forming surface.

Further objects of the invention are apparatuses for digital imaging, in which imaging a radiation source is used for irradiating the object being imaged, and semiconductor sensors are used for detecting the radiation, whereby the area covered by the semiconductor sensors is substantially smaller than the image-forming surface. A special object of the invention is a mammography apparatus applying this technology.

Different imaging methods are used for a variety of applications. In imaging applications relating to medicine and biotechnology, among others, x-ray, gamma or beta radiation is typically passed through the object being imaged and further onto an image-forming surface. In recent years, alongside conventional film-based imaging methods digital imaging systems have been developed, the said digital imaging methods using semiconductor sensors such as CCD sensors (Charge Coupled Device) or CMOS sensors (Complementary Metal-Oxide Semiconductor) as the image-forming surface.

Mammography is a typical area of application of digital imaging relating to medical technology which requires a large image-forming surface, typically at least of 18 x 24 cm, and also high resolution. In mammography, strict limits are also set for acceptable exposure to radiation. Mammographic imaging also requires an image-forming surface, whose active area extends on three sides as close to the outer edge of the imaging area as possible, in order that the chest and both armpits can be positioned for imaging in such a way that as much tissue as possible can be imaged.

Semiconductor sensors are typically made of silicon. One disadvantage of this type of sensor is its high price, since with the increase in size of the sensor, the cost of its manufacture per surface area increases exponentially. The manufacture of one semiconductor sensor thus becomes extremely expensive in applications requiring an extensive image-forming surface.

Attempts have been made to avoid the above problem by producing the image-forming surface in a mosaic-like manner from several smaller semiconductor sensors as described, for example, in GB patent publication 2 305 096. In this type of solution, it becomes a problem to obtain a uniform image-forming surface, since one side of a rectangular semiconductor sensor is typically reserved for control couplings. This means that all sides of the sensor cannot be connected to the active area of another sensor, but there will always remain a small gap between them. To compensate for the disadvantages caused by the gaps, various solutions based on lenses or fibre optics can be used, but the disadvantage of lenses is their poor efficiency and the use of fibre optics incurs major additional costs. In some applications, attempts have been made to solve the problem by producing a sensor with a extensive surface by means of a semiconductor technique based on amorphous silicon, but the resolution obtainable in this manner is not sufficient for medical applications requiring a high level of accuracy, as mammography.

A known solution for obtaining a wide image-forming surface is to arrange semiconductor sensors in a chessboard-like fashion in rows and columns so that essentially every other chessboard pattern square comprises a semiconductor sensor in such a way that in one direction, for example parallel to the rows, the sensors extend beyond the chessboard pattern square, and correspondingly in the orthogonal direction, that is, parallel to the columns, there remains a gap between the sensors. In such a case the semiconductor sensor assembly is arranged to be mobile - in a way that the assembly can be moved twice in the direction where there is a gap between the sensors, and the sensor assembly is irradiated in the initial position and after both

moves of the assembly. In this way the area covered by the sensor assembly as a whole - excluding the squares remaining on the edges of the image-forming surface - can be imaged by three exposures.

The problem with the above arrangement is that the sensor assembly has to be moved and stopped for as many as three different exposures. This means that the mechanical structure of the imaging apparatus becomes difficult to implement, the frequent exposures place a load on the radiation source, and the imaging time is prolonged.

To avoid excessive exposure to radiation, in medical applications it is often necessary to arrange for collimation, that is, by means of shadowing, to limit radiation at any time only to the area covered by the sensors. The implementation of collimation then causes a problem area of its own. Since, for example, a typical x-ray source focal spot is not an infinitely small point, but has finite dimensions, for example, of the order 0.3 x 0.3 mm, depending on the structure of the equipment, a half-shadowed area a few millimetres wide is formed at the edges of the radiation field, in which area radiation is incomplete. Because of this, collimation must be planned so that there is a certain amount either of overlap or shortfall at the edge areas, in other words that the areas being imaged either overlap to some extent, or that there is no overlap. However, when the chessboard pattern according to the prior art is used, the overlap causes the radiation dose to double in the lattice-like area, at points even to triple, in the object being imaged, and the shortfall on the other hand forms a lattice-like area in the image being formed, which area has less image information than elsewhere, or where it is completely lacking.

The edge areas of the image-forming surface constitute a further problem, since they cannot be irradiated completely. Empty squares remain on the edges of the image-forming surface, that is, image information is obtained only from the area of every

other square, in which case the edges of the image-forming surface form a kind of castellated pattern.

The aim of the invention is to develop an imaging method and apparatuses for implementing the method in such a way that the foregoing problems can be solved, or at least the disadvantages caused by them can be diminished. These aims are achieved by means of the method and apparatuses, whose characteristic features are defined in the enclosed claims, especially in the characterising parts of the independent claims.

The aims of the invention are achieved especially by arranging the semiconductor sensors so that the entire image-forming surface can be imaged by means of two irradiations, moving the semiconductor sensors only once between the two irradiations.

According to one advantageous embodiment of the invention, the semiconductor sensors are arranged so as to form a bar having essentially the shape of a rectangle, so that the said bar comprises several semiconductor sensors - in either one or two columns. The couplings for controlling the semiconductor sensors, and the other couplings needed, are then preferably situated on one side of the sensor.

According to a further advantageous embodiment of the invention, the said bars are arranged at a distance from one another to form a sensor matrix so that the distance between the bars is at most equal to the width of the active area of the semiconductor sensors of the said bars.

The invention is based on arranging the semiconductor sensors in such a - preferably rectangular - form that by moving the semiconductor sensors from the first position to the second position and by irradiating the object to be imaged in both positions, the entire image-forming surface can be covered, which means that by combining these two images a uniform image of the entire image-forming surface is obtained. By means of a colli-

mator matrix it is possible in both positions to limit radiation only to the area covered by the semiconductor sensors.

An advantage of the method and apparatus according to the invention is the easily implemented mechanical structure as regards both the sensor assembly and collimation. The sensor and collimator assembly can also be made plain to align and of robust structure. As the number of exposures decreases, the thermal stress on the radiation source also decreases, on account of which the cooling of the radiation source does not constitute a significant problem, nor is it necessary to wait for the radiation source to cool, which would slow down imaging work. The time spent on imaging a single object is also reduced since the entire image-forming surface can be covered by just two exposures. Furthermore, the empty squares at the edge of the image-forming surface are eliminated, that is, straight edges are obtained for the image-forming surface, and the disadvantages caused by collimation described above are also less significant than in prior art solutions.

The invention is described in greater detail below with the help of its advantageous embodiments and with reference to the enclosed figures, of which figures

Figure 1 shows, by way of an example, an embodiment of the invention in the context of mammographic imaging,

Figure 2a shows one advantageous structure of the sensor bar,

Figure 2b shows another advantageous structure of the sensor bar,

Figure 3 shows one advantageous structure of the sensor matrix, and

Figure 4 shows one advantageous way of forming a sensor bar.

In Figure 1, the application of the invention is described by way of an example in the context of mammographic imaging, but the invention may obviously also be used for any other corresponding digital imaging. According to Figure 1, the semiconductor sensors 1 are arranged to form essentially rectangular sensor bars 2, which sensor bars 2 form a mobile sensor matrix 3. The sensor bars 2 are arranged in the sensor matrix 3 in a fixed position with respect to one another, so that between the sensor bars 2 remains a vacant area narrower than a sensor bar 2. Collimation is carried out by means of essentially rectangular collimators 4, which then form a mobile collimator matrix 5, in which the collimators 4 are placed in a fixed position with respect to one another. The collimator matrix 5 is positioned for imaging in such a way that the collimators 4 shadow the vacant areas between the sensor bars 2 of the sensor matrix 3, as seen from the radiation source 6, in which case no radiation will be focused on these areas. The collimator construction can be situated, as in Figure 1, either in the immediate vicinity of the object being imaged or at a distance from it - even in the immediate vicinity of the radiation source. The object 7 being imaged, in mammography typically the breast, is placed between the collimator matrix 5 and the sensor matrix 3 and the object is irradiated with the radiation from the radiation source 6. The semiconductor sensors 1 detect the radiation they receive, on the basis of which digital image information is formed with the help of a sample and hold circuit 8 and an analog-to-digital converter 9. If necessary, the image information can be edited further, for example, to compensate for dark current and possible non-linearities. The image information is transmitted further either to processing means 10 or memory means 11. After this, and with the object 7 being imaged still remaining in the same position, the sensor matrix 3 is moved in the sideways direction so that the sensor bars 2 will cover essentially the same areas where the vacant areas between sensor bars 2 were situated before the move. In mammography, the object 7 being imaged, that is, the breast, is kept in place with the help of pressing means (not shown). The collimator matrix 5 is moved correspondingly so that the collimators 4 then shadow

the vacant areas between the sensor bars 2 conforming to the new position of the sensor matrix 3. The object 7 being imaged is irradiated for a second time with the new settings of the sensor matrix 3 and collimator matrix 5, and the image information formed on the basis of the second irradiation is combined with the image information formed on the basis of the first irradiation in the processing means 10. By means of two irradiations, therefore, an image of the entire image-forming surface can be obtained.

With the solution described above considerable advantages are achieved with respect to the prior art. The mechanical structure according to the invention is easier to implement as regards both the sensor matrix and collimation. The sensor matrix formed of rectangular sensor bars is plain to align and has a robust structure. The collimator matrix is also easy to construct and it is easy to align with respect to the sensor matrix. Furthermore, as the object being imaged is only irradiated twice, the load on the radiation source decreases, which prolongs its service life and speeds up the imaging work, because the need to cool the radiation source is lessened, and the time spent on imaging a single object is also shortened.

Compared with a uniform image-forming surface, the arrangement relating to the invention requires only half of the active surface area of the semiconductor sensors. On the other hand, when using, for example, CMOS sensors, the invention can, if so desired, be realised so that no arrangement based on lenses or fibre optics will be needed to compensate for the gaps between the semiconductor sensors.

As the sensor and collimator matrix are only moved once, the accuracy of a move carried out in only one direction needs to be looked after. It is, therefore, possible to dimension and align the collimator matrix in such a way that the overlap of the areas being irradiated is significantly reduced, and thus the disadvantages of collimation are diminished in comparison to known solutions.

The final formation of a digital image can be carried out by connecting the imaging equipment with a computer, in which case the computer's memory and processing means can be utilised. The processing means 10 relating to Figure 1 can also be realised, for example, by a dedicated Application Specific Integrated Circuit (ASIC), to which are connected memory means 11, for example, a FLASH memory. The formation of final image information is known as such to a person skilled in the art, and its more detailed description is not necessary for the implementation of the invention.

According to one advantageous embodiment of the invention, the sensor bars 2 to be placed in the sensor matrix 3 are formed of semiconductor sensors 1, which are substantially smaller than the sensor bars 2. Figures 2a and 2b show two advantageous ways of arranging the semiconductor sensors 1 to form a sensor bar 2. In both figures, the sensor bar 2 comprises semiconductor sensors 1a, 1b, ..., which are arranged to form a rectangular sensor bar 2. A typical semiconductor sensor 1n comprises an active area A, which is used for detecting the radiation received, and a coupling area K, through which the control signals of the sensor 1n and the charge readout, that is, in this case the collection of image information, are transmitted. In a semiconductor 1n, at least one side is typically reserved for the coupling area K, and thus the semiconductor sensor 1n can advantageously be connected to another semiconductor sensor 1n on three sides, as shown in Figure 2b, if it is desirable that the active areas of the sensors form a uniform surface. The sensor bar 2 can thus be formed of either one (1 x N) or two (2 x N) columns of semiconductor sensors 1n. The distance between sensor bars 2 in the sensor matrix 3 is determined on the basis of the width #A of the active area A of the semiconductor sensors 1 used, in other words, the maximum distance between the sensor bars 2 can, in the case of single column sensor bars 2, equal the width #A of A (Figure 3), or in the case of sensor bars with two columns, 2 x the width of A, that is, 2 x #A.

When the sensor bar 2 is formed of semiconductor sensors 1n which are substantially smaller than the sensor bar 2, no large and therefore expensive semiconductor sensors are required. Further cost savings ensue from the fact that if a single semiconductor sensor 1n is damaged, it can be replaced without having to replace the entire sensor bar 2.

Figure 3 shows an advantageous manner of arranging the sensor bars 2 according to the invention, so that the image-forming surface is made as large as possible and the edges of the image-forming surface become uniform. The sensor bars 2 consist of one column (1 x N) of semiconductor sensors 1n, in which case the outermost sensor bars 2 are placed so that the coupling area K of the semiconductor sensors 1n is placed towards the inside of the sensor matrix 3. The image-forming surface will then extend over the entire area covered by the sensor matrix 3 and the so-called castellated pattern will not be formed on the edges of the image-forming surface. The positioning of the coupling areas of the sensor bars 2 inside the sensor matrix 3 may be selected freely, provided that the vacant areas between the sensor bars are correctly dimensioned. The sensor bars 2 may obviously also be formed of two columns (2 x N) of semiconductor sensors 1n, but if the outermost sensor bars 2 are also formed in this manner, the active area of the sensor matrix 3 cannot be made to extend sideways all the way to the edges of the image-forming surface.

An application of the invention may obviously also be envisaged where a sensor matrix is constructed of different types of sensor bars, that is, for example sensor bars with active areas of varying widths, one or two columns, having coupling areas on opposite sides and/or even sensor bars based on different technologies. However, and especially if this type of sensor bar is used in applications where radiation has to be limited to the sensor matrix area, some of the advantages obtained with the invention may be lost.

According to one advantageous embodiment of the invention, the movements of the collimator matrix and sensor matrix are not connected to each other, but each matrix is moved separately. This is preferably done by first moving the sensor matrix into its new position and then aligning the collimator matrix according to the sensor matrix. The invention may, however, naturally also be implemented so that the movements of the collimator matrix and sensor matrix are synchronised.

The movement of the sensors and/or collimators may be carried out, for example, by means of solenoids or separate servomotors. The use of a solenoid is especially recommended since it is an economical, accurate and reliable component. The invention particularly makes it possible to use solenoids since, according to the invention, the sensors and/or collimators need to be moved only between two positions.

According to one advantageous embodiment of the invention, the semiconductor sensors are CMOS sensors based on direct detection of radiation, the said sensors having certain advantages compared with conventional semiconductor sensors. With the CMOS sensors improved resolution is achieved compared with conventional semiconductor sensors and due to the parallel bus type data transfer, they enable more rapid transfer of image information. CMOS technology is the most widely applied semiconductor technology, which means that the availability of CMOS circuits is good, and their production costs will fall as the technology develops.

Figure 4 shows an advantageous way, in accordance with the invention, of forming the sensor bar of CMOS sensors. The CMOS sensors 13, 14,... are connected to a preferably rectangular radiation detector 12 with substantially the same external dimensions as the bar. The detector 12 is preferably made of doped silicon (Si) or a cadmium zinc telluride compound (CdZnTe). Between the top and bottom surfaces of the detector is generated a biasing voltage Ur, by means of which the charge generated by the radiation is collected to the nearest pixel.

The charge generated is transmitted to the CMOS sensors 13, 14, ..., which are connected to the detector 12, preferably by means of microscopic ball conductors, that is, by means of so-called bump bonding. In the coupling area of the CMOS sensors, control signals can be fed to the sensors and the radiation detected can be read by means of pins at the end of the sensors, for the purpose of forming image information. The detection of radiation by means of CMOS sensors is known as such to a person skilled in the art.

In accordance with the invention, semiconductor sensors known as such, which are based on the use of lenses or fibre optics, can obviously also be used, in which case the coupling areas can also be located in the three-dimensional structure of the sensor on a surface that allows the whole width of the sensor to be utilised as an active radiation-detecting area. This means, however, that some of the advantages achieved with the invention are at the same time lost.

Although the invention is described above by way of an example in the context of mammography, it can obviously also be used in connection with any other similar imaging application. In accordance with the invention, any radiation that is detectable by semiconductor sensors can be used.

The invention is particularly useful in imaging applications relating to medical technology, where x-ray or gamma radiation is typically used, and in biotechnical applications where beta radiation is typically used. The invention is furthermore applicable to industrial testing and quality control methods utilising radioscopy.

It is obvious to a person skilled in the art that as technology develops, the basic idea of the invention can be implemented in various ways, which means that its different embodiments are not limited to the foregoing examples, but may vary within the scope of protection defined in the enclosed claims.

Claims

1. A digital imaging method, in which method the object being imaged is irradiated and the radiation is detected by means of semiconductor sensors, which comprise an active area, and in their three-dimensional structure an area or areas for control couplings, whereby the area covered by the semiconductor sensors is substantially smaller than the image-forming surface of the object being imaged, characterized in that the object being imaged is irradiated twice and the semiconductor sensors are moved to a new position between the irradiations, in which case the sensors are arranged to cover the image-forming surface so that the entire image-forming surface can be imaged.

2. An imaging method as claimed in claim 1, characterized in that the coupling area of the semiconductor sensor is arranged on one of its sides.

3. An imaging method as claimed in claim 1 or 2, characterized in that the semiconductor sensors are arranged to form a substantially rectangular bar.

4. An imaging method as claimed in claim 3, characterized in that the said bar is arranged to be formed of one column (1 x N) of semiconductor sensors.

5. An imaging method as claimed in claim 4, characterized in that the semiconductor sensors are arranged in the bar so that their coupling areas are located essentially on one side of the bar.

6. An imaging method as claimed in any of the claims 3 to 6, characterized in that the bars are arranged to form a sensor matrix, in which the bars are arranged at a distance from one another so that the said distance between the bars is at most equal to the width of the active area formed by the semiconductor sensors in the bars.

7. An imaging method as claimed in claim 6, characterized in that the outermost bars of the sensor matrix are arranged so that their active area comprises the outer edges of the image-forming surface.

8. An imaging method as claimed in claim 3, characterized in that the said bar is arranged to comprise two columns (2 x N) of semiconductor sensors.

9. An imaging method as claimed in claim 8, characterized in that the semiconductor sensors are arranged in the bar so that their coupling areas are located essentially on two sides of the bar.

10. An imaging method as claimed in claim 8 or 9, characterized in that the bars are arranged to form a sensor matrix, in which the bars are arranged at a distance from one another so that the said distance is at most equal to the width of the active area formed by the semiconductor sensors in the bars.

11. An imaging method as claimed in any of the claims 1 to 10, characterized in that the radiation is limited essentially to the area covered by the sensors, for which limiting function a suitable collimator construction is preferably used.

12. An imaging method as claimed in claim 11, characterized in that the collimator construction and the sensors are moved separately.

13. An imaging method as claimed in any of the claims 1 to 12, characterized in that the movement of the collimator construction and/or the sensors is carried out by means of solenoids.

14. An imaging method as claimed in any of the claims 1 to 13, characterized in that CMOS sensors are used as the semiconductor sensors.

15. An imaging method as claimed in any of the claims 1 to 14, characterized in that the method is used in the context of mammographic imaging.

16. An apparatus for digital imaging, in which imaging a radiation source is used for irradiating the object to be imaged and semiconductor sensors are used for detecting the radiation, whereby the semiconductor sensors (1) comprise an active area (A), and in their three-dimensional structure, an area or areas for control couplings (K), the area covered by the said semiconductor sensors (1) being substantially smaller than the image-forming surface, characterized in that the apparatus comprises means for moving the semiconductor sensors (1) to a new position between two irradiations, in which apparatus the semiconductor sensors (1) and the means for moving them are arranged so that the area covered by the semiconductor sensors (1) in their initial position, combined with the area covered by the semiconductor sensors (1) in their position after the move, cover the entire image-forming surface.

17. An apparatus as claimed in claim 16, characterized in that the coupling area (K) of the semiconductor sensor (1) is arranged on one of its sides.

18. An apparatus as claimed in claim 16 or 17, characterized in that several semiconductor sensors (1n) are arranged to form an essentially rectangular bar (2).

19. An apparatus as claimed in claim 18, characterized in that the said bar (2) comprises one column (1 x N) of semiconductor sensors (1n).

20. An apparatus as claimed in claim 19, characterized in that the semiconductor sensors (1n) are arranged in the bar (2) so that their coupling areas (K) are essentially located on one side of the bar (2).

21. An apparatus as claimed in any of the claims 18 to 20, characterized in that the bars (2) form a sensor matrix (3) in which the bars (2) are arranged at a distance (A#) from one another, in such a way that the said distance (A#) is at most equal to the width of the active area (A) formed by the semiconductor sensors (1n) in the said bars (2).

22. An apparatus as claimed in claim 21, characterized in that the active area (A) of the outermost bars (2) of the sensor matrix (3) comprises the outer edges of the image-forming surface.

23. An apparatus as claimed in claim 18, characterized in that the said bar (2) comprises two columns (2 x N) of semiconductor sensors (1n).

24. An apparatus as claimed in claim 23, characterized in that the semiconductor sensors (1n) are arranged in the bar (2) in such a way that their coupling areas (K) are essentially located on two sides of the bar (2).

25. An apparatus as claimed in claim 23 or 24, characterized in that the said bars (2) form a sensor matrix (3) in which the bars (2) are arranged at a distance (A#) from one another, in such a way that the said distance (A#) is at most equal to the width of the active area (A) formed by the semiconductor sensors (1n) in the said bars (2).

26. An apparatus as claimed in any of the claims 16 to 25, characterized in that it comprises means for limiting radiation essentially to the area covered by the sensors (1), the said means preferably comprising a suitable collimator construction (4, 5).

27. An apparatus as claimed in claim 26, characterized in that it comprises separate means for moving, on the one hand, the collimator construction (4, 5), and on the other, the sensors (1).

28. An apparatus as claimed in any of the claims 16 to 27, characterized in that the said means for moving the collimators (4, 5) and/or the sensors (1) comprise a solenoid.

29. An apparatus as claimed in any of the claims 16 to 28, characterized in that the semiconductor sensors (1) are CMOS sensors.

30. A mammography apparatus comprising an apparatus as claimed in any of the claims 16 to 29 for the digital imaging of the tissue being imaged.

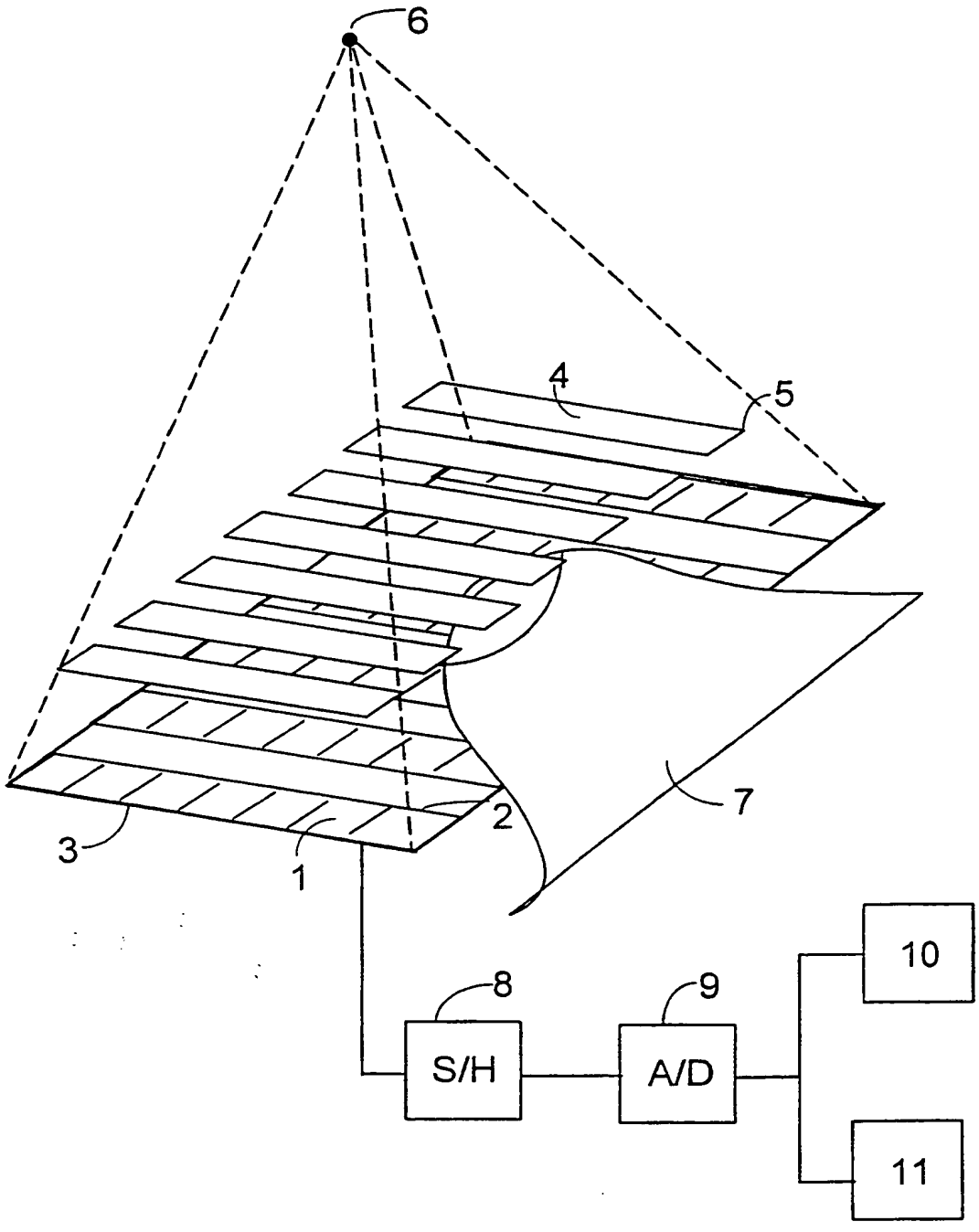

FIG. 1

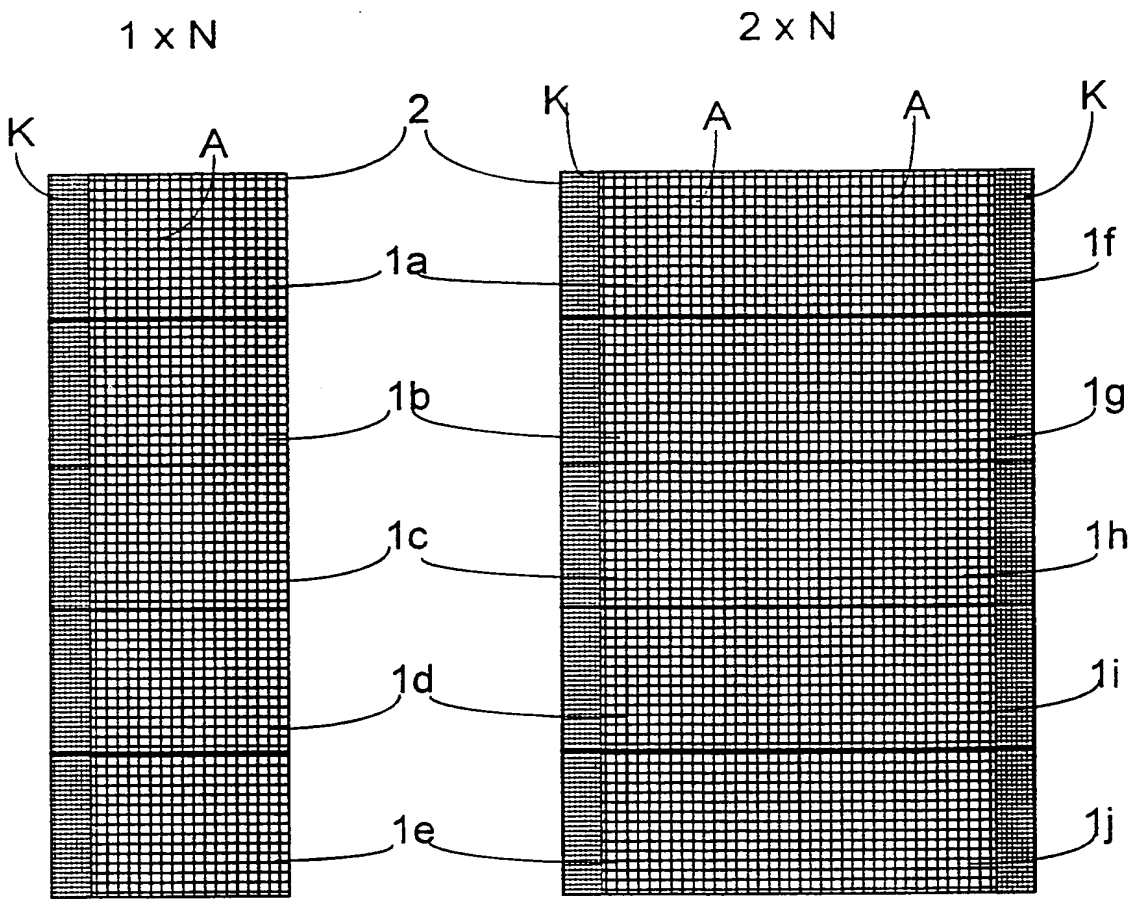

FIG. 2a FIG. 2b

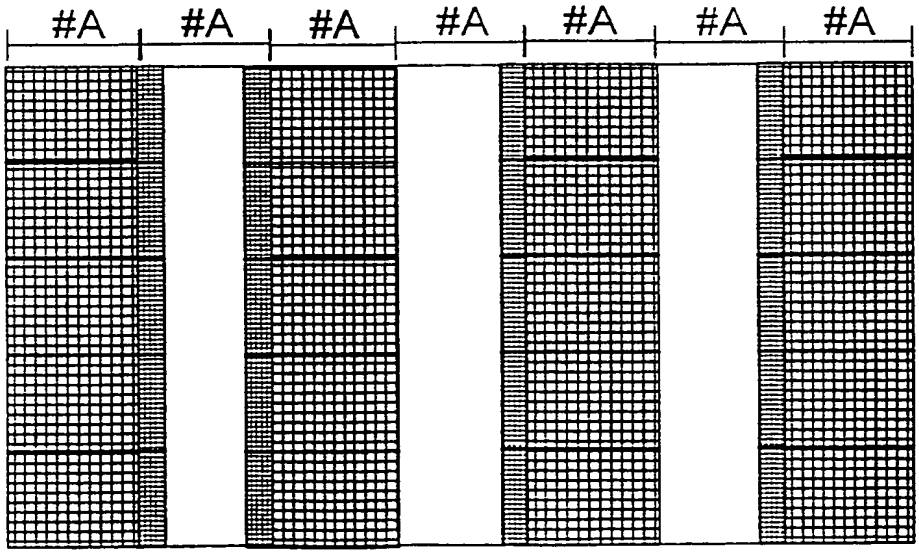

FIG. 3

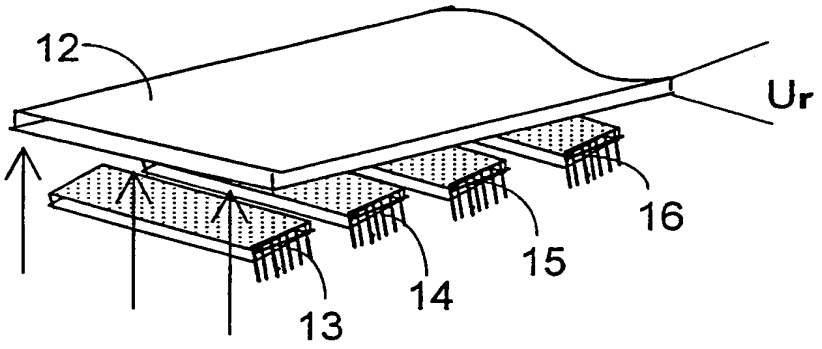

FIG. 4

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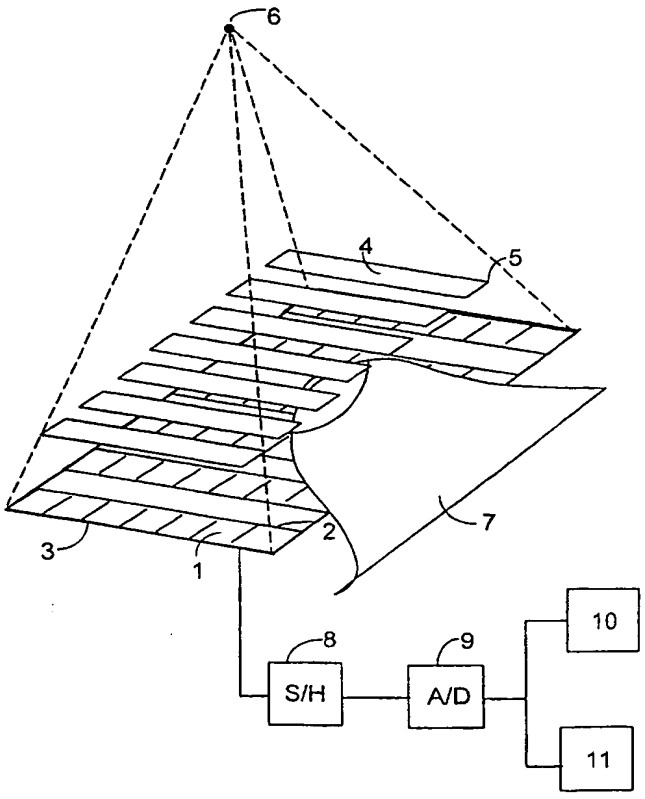
(57) Abstract

A digital imaging method, in which the object being imaged is irradiated and the radiation is detected by means of semiconductor sensors (1), covering an area which is smaller than the image–forming surface. The semiconductor sensors (1) are arranged in such a way that the image–forming surface can be imaged in two irradiations by moving the semiconductor sensors (1) between the irradiations. The radiation can be limited to the area covered by the sensors (1) by means of collimators (4). The semiconductor sensors (1) are arranged to form advantageously rectangular bars (2), which comprise several semiconductor sensors (1) in the form of one or two columns, in which the bars (2) are arranged advantageously at a distance from one another, the said distance between the bars being at most equal to the width of the active area of the semiconductor sensors of the bars.



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Method and apparatuses for digital imaging

The object of the invention is a digital imaging method, in which method the object being imaged is irradiated and the radiation is detected by means of semiconductor sensors covering an area which is substantially smaller than the image-forming surface.

Further objects of the invention are apparatuses for digital imaging, in which imaging a radiation source is used for irradiating the object being imaged, and semiconductor sensors are used for detecting the radiation, whereby the area covered by the semiconductor sensors is substantially smaller than the image-forming surface. A special object of the invention is a mammography apparatus applying this technology.

Different imaging methods are used for a variety of applications. In imaging applications relating to medicine and biotechnology, among others, x-ray, gamma or beta radiation is typically passed through the object being imaged and further onto an image-forming surface. In recent years, alongside conventional film-based imaging methods digital imaging systems have been developed, the said digital imaging methods using semiconductor sensors such as CCD sensors (Charge Coupled Device) or CMOS sensors (Complementary Metal-Oxide Semiconductor) as the image-forming surface.

Mammography is a typical area of application of digital imaging relating to medical technology which requires a large image-forming surface, typically at least of 18 x 24 cm, and also high resolution. In mammography, strict limits are also set for acceptable exposure to radiation. Mammographic imaging also requires an image-forming surface, whose active area extends on three sides as close to the outer edge of the imaging area as possible, in order that the chest and both armpits can be positioned for imaging in such a way that as much tissue as possible can be imaged.

Semiconductor sensors are typically made of silicon. One disadvantage of this type of sensor is its high price, since with the increase in size of the sensor, the cost of its manufacture per surface area increases exponentially. The manufacture of one semiconductor sensor thus becomes extremely expensive in applications requiring an extensive image-forming surface.

Attempts have been made to avoid the above problem by producing the image-forming surface in a mosaic-like manner from several smaller semiconductor sensors as described, for example, in GB patent publication 2 305 096. In this type of solution, it becomes a problem to obtain a uniform image-forming surface, since one side of a rectangular semiconductor sensor is typically reserved for control couplings. This means that all sides of the sensor cannot be connected to the active area of another sensor, but there will always remain a small gap between them. To compensate for the disadvantages caused by the gaps, various solutions based on lenses or fibre optics can be used, but the disadvantage of lenses is their poor efficiency and the use of fibre optics incurs major additional costs. In some applications, attempts have been made to solve the problem by producing a sensor with a extensive surface by means of a semiconductor technique based on amorphous silicon, but the resolution obtainable in this manner is not sufficient for medical applications requiring a high level of accuracy, as mammography.

A known solution for obtaining a wide image-forming surface is to arrange semiconductor sensors in a chessboard-like fashion in rows and columns so that essentially every other chessboard pattern square comprises a semiconductor sensor in such a way that in one direction, for example parallel to the rows, the sensors extend beyond the chessboard pattern square, and correspondingly in the orthogonal direction, that is, parallel to the columns, there remains a gap between the sensors. In such a case the semiconductor sensor assembly is arranged to be mobile - in a way that the assembly can be moved twice in the direction where there is a gap between the sensors, and the sensor assembly is irradiated in the initial position and after both

moves of the assembly. In this way the area covered by the sensor assembly as a whole - excluding the squares remaining on the edges of the image-forming surface - can be imaged by three exposures.

The problem with the above arrangement is that the sensor assembly has to be moved and stopped for as many as three different exposures. This means that the mechanical structure of the imaging apparatus becomes difficult to implement, the frequent exposures place a load on the radiation source, and the imaging time is prolonged.

To avoid excessive exposure to radiation, in medical applications it is often necessary to arrange for collimation, that is, by means of shadowing, to limit radiation at any time only to the area covered by the sensors. The implementation of collimation then causes a problem area of its own. Since, for example, a typical x-ray source focal spot is not an infinitely small point, but has finite dimensions, for example, of the order 0.3 x 0.3 mm, depending on the structure of the equipment, a half-shadowed area a few millimetres wide is formed at the edges of the radiation field, in which area radiation is incomplete. Because of this, collimation must be planned so that there is a certain amount either of overlap or shortfall at the edge areas, in other words that the areas being imaged either overlap to some extent, or that there is no overlap. However, when the chessboard pattern according to the prior art is used, the overlap causes the radiation dose to double in the lattice-like area, at points even to triple, in the object being imaged, and the shortfall on the other hand forms a lattice-like area in the image being formed, which area has less image information than elsewhere, or where it is completely lacking.

The edge areas of the image-forming surface constitute a further problem, since they cannot be irradiated completely. Empty squares remain on the edges of the image-forming surface, that is, image information is obtained only from the area of every

other square, in which case the edges of the image-forming surface form a kind of castellated pattern.

The aim of the invention is to develop an imaging method and apparatuses for implementing the method in such a way that the foregoing problems can be solved, or at least the disadvantages caused by them can be diminished. These aims are achieved by means of the method and apparatuses, whose characteristic features are defined in the enclosed claims, especially in the characterising parts of the independent claims.

The aims of the invention are achieved especially by arranging the semiconductor sensors so that the entire image-forming surface can be imaged by means of two irradiations, moving the semiconductor sensors only once between the two irradiations.

According to one advantageous embodiment of the invention, the semiconductor sensors are arranged so as to form a bar having essentially the shape of a rectangle, so that the said bar comprises several semiconductor sensors - in either one or two columns. The couplings for controlling the semiconductor sensors, and the other couplings needed, are then preferably situated on one side of the sensor.

According to a further advantageous embodiment of the invention, the said bars are arranged at a distance from one another to form a sensor matrix so that the distance between the bars is at most equal to the width of the active area of the semiconductor sensors of the said bars.

The invention is based on arranging the semiconductor sensors in such a - preferably rectangular - form that by moving the semiconductor sensors from the first position to the second position and by irradiating the object to be imaged in both positions, the entire image-forming surface can be covered, which means that by combining these two images a uniform image of the entire image-forming surface is obtained. By means of a colli-

mator matrix it is possible in both positions to limit radiation only to the area covered by the semiconductor sensors.

An advantage of the method and apparatus according to the invention is the easily implemented mechanical structure as regards both the sensor assembly and collimation. The sensor and collimator assembly can also be made plain to align and of robust structure. As the number of exposures decreases, the thermal stress on the radiation source also decreases, on account of which the cooling of the radiation source does not constitute a significant problem, nor is it necessary to wait for the radiation source to cool, which would slow down imaging work. The time spent on imaging a single object is also reduced since the entire image-forming surface can be covered by just two exposures. Furthermore, the empty squares at the edge of the image-forming surface are eliminated, that is, straight edges are obtained for the image-forming surface, and the disadvantages caused by collimation described above are also less significant than in prior art solutions.

The invention is described in greater detail below with the help of its advantageous embodiments and with reference to the enclosed figures, of which figures

Figure 1 shows, by way of an example, an embodiment of the invention in the context of mammographic imaging,

Figure 2a shows one advantageous structure of the sensor bar,

Figure 2b shows another advantageous structure of the sensor bar,

Figure 3 shows one advantageous structure of the sensor matrix, and

Figure 4 shows one advantageous way of forming a sensor bar.

In Figure 1, the application of the invention is described by way of an example in the context of mammographic imaging, but the invention may obviously also be used for any other corresponding digital imaging. According to Figure 1, the semiconductor sensors 1 are arranged to form essentially rectangular sensor bars 2, which sensor bars 2 form a mobile sensor matrix 3. The sensor bars 2 are arranged in the sensor matrix 3 in a fixed position with respect to one another, so that between the sensor bars 2 remains a vacant area narrower than a sensor bar 2. Collimation is carried out by means of essentially rectangular collimators 4, which then form a mobile collimator matrix 5, in which the collimators 4 are placed in a fixed position with respect to one another. The collimator matrix 5 is positioned for imaging in such a way that the collimators 4 shadow the vacant areas between the sensor bars 2 of the sensor matrix 3, as seen from the radiation source 6, in which case no radiation will be focused on these areas. The collimator construction can be situated, as in Figure 1, either in the immediate vicinity of the object being imaged or at a distance from it - even in the immediate vicinity of the radiation source. The object 7 being imaged, in mammography typically the breast, is placed between the collimator matrix 5 and the sensor matrix 3 and the object is irradiated with the radiation from the radiation source 6. The semiconductor sensors 1 detect the radiation they receive, on the basis of which digital image information is formed with the help of a sample and hold circuit 8 and an analog-to-digital converter 9. If necessary, the image information can be edited further, for example, to compensate for dark current and possible non-linearities. The image information is transmitted further either to processing means 10 or memory means 11. After this, and with the object 7 being imaged still remaining in the same position, the sensor matrix 3 is moved in the sideways direction so that the sensor bars 2 will cover essentially the same areas where the vacant areas between sensor bars 2 were situated before the move. In mammography, the object 7 being imaged, that is, the breast, is kept in place with the help of pressing means (not shown). The collimator matrix 5 is moved correspondingly so that the collimators 4 then shadow

the vacant areas between the sensor bars 2 conforming to the new position of the sensor matrix 3. The object 7 being imaged is irradiated for a second time with the new settings of the sensor matrix 3 and collimator matrix 5, and the image information formed on the basis of the second irradiation is combined with the image information formed on the basis of the first irradiation in the processing means 10. By means of two irradiations, therefore, an image of the entire image-forming surface can be obtained.

With the solution described above considerable advantages are achieved with respect to the prior art. The mechanical structure according to the invention is easier to implement as regards both the sensor matrix and collimation. The sensor matrix formed of rectangular sensor bars is plain to align and has a robust structure. The collimator matrix is also easy to construct and it is easy to align with respect to the sensor matrix. Furthermore, as the object being imaged is only irradiated twice, the load on the radiation source decreases, which prolongs its service life and speeds up the imaging work, because the need to cool the radiation source is lessened, and the time spent on imaging a single object is also shortened.

Compared with a uniform image-forming surface, the arrangement relating to the invention requires only half of the active surface area of the semiconductor sensors. On the other hand, when using, for example, CMOS sensors, the invention can, if so desired, be realised so that no arrangement based on lenses or fibre optics will be needed to compensate for the gaps between the semiconductor sensors.

As the sensor and collimator matrix are only moved once, the accuracy of a move carried out in only one direction needs to be looked after. It is, therefore, possible to dimension and align the collimator matrix in such a way that the overlap of the areas being irradiated is significantly reduced, and thus the disadvantages of collimation are diminished in comparison to known solutions.

The final formation of a digital image can be carried out by connecting the imaging equipment with a computer, in which case the computer's memory and processing means can be utilised. The processing means 10 relating to Figure 1 can also be realised, for example, by a dedicated Application Specific Integrated Circuit (ASIC), to which are connected memory means 11, for example, a FLASH memory. The formation of final image information is known as such to a person skilled in the art, and its more detailed description is not necessary for the implementation of the invention.

According to one advantageous embodiment of the invention, the sensor bars 2 to be placed in the sensor matrix 3 are formed of semiconductor sensors 1, which are substantially smaller than the sensor bars 2. Figures 2a and 2b show two advantageous ways of arranging the semiconductor sensors 1 to form a sensor bar 2. In both figures, the sensor bar 2 comprises semiconductor sensors 1a, 1b, ..., which are arranged to form a rectangular sensor bar 2. A typical semiconductor sensor 1n comprises an active area A, which is used for detecting the radiation received, and a coupling area K, through which the control signals of the sensor 1n and the charge readout, that is, in this case the collection of image information, are transmitted. In a semiconductor 1n, at least one side is typically reserved for the coupling area K, and thus the semiconductor sensor 1n can advantageously be connected to another semiconductor sensor 1n on three sides, as shown in Figure 2b, if it is desirable that the active areas of the sensors form a uniform surface. The sensor bar 2 can thus be formed of either one (1 x N) or two (2 x N) columns of semiconductor sensors 1n. The distance between sensor bars 2 in the sensor matrix 3 is determined on the basis of the width #A of the active area A of the semiconductor sensors 1 used, in other words, the maximum distance between the sensor bars 2 can, in the case of single column sensor bars 2, equal the width #A of A (Figure 3), or in the case of sensor bars with two columns, 2 x the width of A, that is, 2 x #A.

When the sensor bar 2 is formed of semiconductor sensors 1n which are substantially smaller than the sensor bar 2, no large and therefore expensive semiconductor sensors are required. Further cost savings ensue from the fact that if a single semiconductor sensor 1n is damaged, it can be replaced without having to replace the entire sensor bar 2.

Figure 3 shows an advantageous manner of arranging the sensor bars 2 according to the invention, so that the image-forming surface is made as large as possible and the edges of the image-forming surface become uniform. The sensor bars 2 consist of one column (1 x N) of semiconductor sensors 1n, in which case the outermost sensor bars 2 are placed so that the coupling area K of the semiconductor sensors 1n is placed towards the inside of the sensor matrix 3. The image-forming surface will then extend over the entire area covered by the sensor matrix 3 and the so-called castellated pattern will not be formed on the edges of the image-forming surface. The positioning of the coupling areas of the sensor bars 2 inside the sensor matrix 3 may be selected freely, provided that the vacant areas between the sensor bars are correctly dimensioned. The sensor bars 2 may obviously also be formed of two columns (2 x N) of semiconductor sensors 1n, but if the outermost sensor bars 2 are also formed in this manner, the active area of the sensor matrix 3 cannot be made to extend sideways all the way to the edges of the image-forming surface.

An application of the invention may obviously also be envisaged where a sensor matrix is constructed of different types of sensor bars, that is, for example sensor bars with active areas of varying widths, one or two columns, having coupling areas on opposite sides and/or even sensor bars based on different technologies. However, and especially if this type of sensor bar is used in applications where radiation has to be limited to the sensor matrix area, some of the advantages obtained with the invention may be lost.

According to one advantageous embodiment of the invention, the movements of the collimator matrix and sensor matrix are not connected to each other, but each matrix is moved separately. This is preferably done by first moving the sensor matrix into its new position and then aligning the collimator matrix according to the sensor matrix. The invention may, however, naturally also be implemented so that the movements of the collimator matrix and sensor matrix are synchronised.

The movement of the sensors and/or collimators may be carried out, for example, by means of solenoids or separate servomotors. The use of a solenoid is especially recommended since it is an economical, accurate and reliable component. The invention particularly makes it possible to use solenoids since, according to the invention, the sensors and/or collimators need to be moved only between two positions.

According to one advantageous embodiment of the invention, the semiconductor sensors are CMOS sensors based on direct detection of radiation, the said sensors having certain advantages compared with conventional semiconductor sensors. With the CMOS sensors improved resolution is achieved compared with conventional semiconductor sensors and due to the parallel bus type data transfer, they enable more rapid transfer of image information. CMOS technology is the most widely applied semiconductor technology, which means that the availability of CMOS circuits is good, and their production costs will fall as the technology develops.

Figure 4 shows an advantageous way, in accordance with the invention, of forming the sensor bar of CMOS sensors. The CMOS sensors 13, 14,... are connected to a preferably rectangular radiation detector 12 with substantially the same external dimensions as the bar. The detector 12 is preferably made of doped silicon (Si) or a cadmium zinc telluride compound (CdZnTe). Between the top and bottom surfaces of the detector is generated a biasing voltage Ur, by means of which the charge generated by the radiation is collected to the nearest pixel.

The charge generated is transmitted to the CMOS sensors 13, 14, ..., which are connected to the detector 12, preferably by means of microscopic ball conductors, that is, by means of so-called bump bonding. In the coupling area of the CMOS sensors, control signals can be fed to the sensors and the radiation detected can be read by means of pins at the end of the sensors, for the purpose of forming image information. The detection of radiation by means of CMOS sensors is known as such to a person skilled in the art.

In accordance with the invention, semiconductor sensors known as such, which are based on the use of lenses or fibre optics, can obviously also be used, in which case the coupling areas can also be located in the three-dimensional structure of the sensor on a surface that allows the whole width of the sensor to be utilised as an active radiation-detecting area. This means, however, that some of the advantages achieved with the invention are at the same time lost.

Although the invention is described above by way of an example in the context of mammography, it can obviously also be used in connection with any other similar imaging application. In accordance with the invention, any radiation that is detectable by semiconductor sensors can be used.

The invention is particularly useful in imaging applications relating to medical technology, where x-ray or gamma radiation is typically used, and in biotechnical applications where beta radiation is typically used. The invention is furthermore applicable to industrial testing and quality control methods utilising radioscopy.

It is obvious to a person skilled in the art that as technology develops, the basic idea of the invention can be implemented in various ways, which means that its different embodiments are not limited to the foregoing examples, but may vary within the scope of protection defined in the enclosed claims.

Claims

1. A digital imaging method, in which method the object being imaged is irradiated and the radiation is detected by means of semiconductor sensors, which comprise an active area, and in their three-dimensional structure an area or areas for control couplings, whereby the area covered by the semiconductor sensors is substantially smaller than the image-forming surface of the object being imaged, characterized in that the object being imaged is irradiated twice and the semiconductor sensors are moved to a new position between the irradiations, in which case the sensors are arranged to cover the image-forming surface so that the entire image-forming surface can be imaged.

2. An imaging method as claimed in claim 1, characterized in that the coupling area of the semiconductor sensor is arranged on one of its sides.

3. An imaging method as claimed in claim 1 or 2, characterized in that the semiconductor sensors are arranged to form a substantially rectangular bar.

4. An imaging method as claimed in claim 3, characterized in that the said bar is arranged to be formed of one column (1 x N) of semiconductor sensors.

5. An imaging method as claimed in claim 4, characterized in that the semiconductor sensors are arranged in the bar so that their coupling areas are located essentially on one side of the bar.

6. An imaging method as claimed in any of the claims 3 to 6, characterized in that the bars are arranged to form a sensor matrix, in which the bars are arranged at a distance from one another so that the said distance between the bars is at most equal to the width of the active area formed by the semiconductor sensors in the bars.

7. An imaging method as claimed in claim 6, characterized in that the outermost bars of the sensor matrix are arranged so that their active area comprises the outer edges of the image-forming surface.

8. An imaging method as claimed in claim 3, characterized in that the said bar is arranged to comprise two columns (2 x N) of semiconductor sensors.

9. An imaging method as claimed in claim 8, characterized in that the semiconductor sensors are arranged in the bar so that their coupling areas are located essentially on two sides of the bar.

10. An imaging method as claimed in claim 8 or 9, characterized in that the bars are arranged to form a sensor matrix, in which the bars are arranged at a distance from one another so that the said distance is at most equal to the width of the active area formed by the semiconductor sensors in the bars.

11. An imaging method as claimed in any of the claims 1 to 10, characterized in that the radiation is limited essentially to the area covered by the sensors, for which limiting function a suitable collimator construction is preferably used.

12. An imaging method as claimed in claim 11, characterized in that the collimator construction and the sensors are moved separately.

13. An imaging method as claimed in any of the claims 1 to 12, characterized in that the movement of the collimator construction and/or the sensors is carried out by means of solenoids.

14. An imaging method as claimed in any of the claims 1 to 13, characterized in that CMOS sensors are used as the semiconductor sensors.

15. An imaging method as claimed in any of the claims 1 to 14, characterized in that the method is used in the context of mammographic imaging.

16. An apparatus for digital imaging, in which imaging a radiation source is used for irradiating the object to be imaged and semiconductor sensors are used for detecting the radiation, whereby the semiconductor sensors (1) comprise an active area (A), and in their three-dimensional structure, an area or areas for control couplings (K), the area covered by the said semiconductor sensors (1) being substantially smaller than the image-forming surface, characterized in that the apparatus comprises means for moving the semiconductor sensors (1) to a new position between two irradiations, in which apparatus the semiconductor sensors (1) and the means for moving them are arranged so that the area covered by the semiconductor sensors (1) in their initial position, combined with the area covered by the semiconductor sensors (1) in their position after the move, cover the entire image-forming surface.

17. An apparatus as claimed in claim 16, characterized in that the coupling area (K) of the semiconductor sensor (1) is arranged on one of its sides.

18. An apparatus as claimed in claim 16 or 17, characterized in that several semiconductor sensors (1n) are arranged to form an essentially rectangular bar (2).

19. An apparatus as claimed in claim 18, characterized in that the said bar (2) comprises one column (1 x N) of semiconductor sensors (1n).

20. An apparatus as claimed in claim 19, characterized in that the semiconductor sensors (1n) are arranged in the bar (2) so that their coupling areas (K) are essentially located on one side of the bar (2).

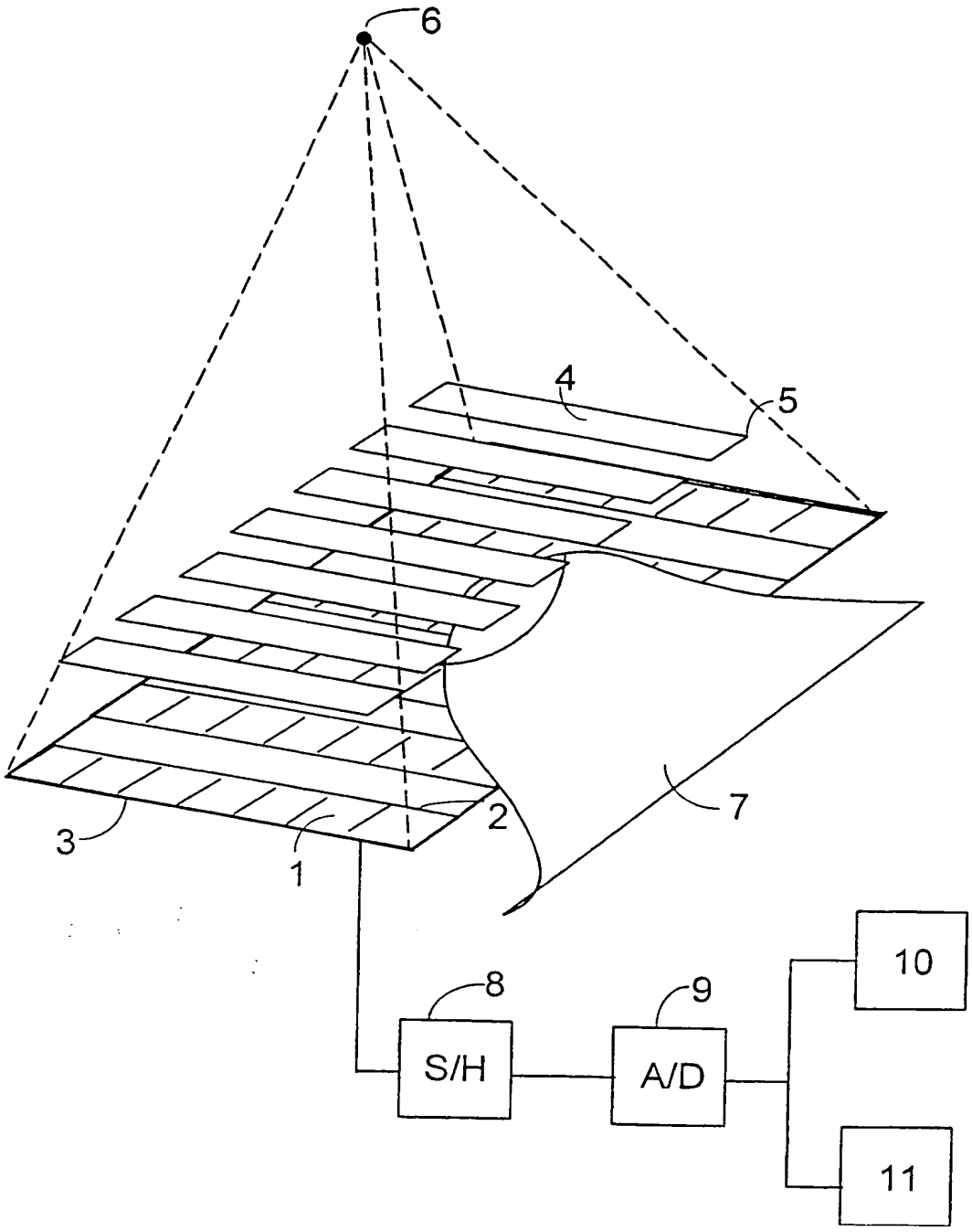

FIG. 1

1 x N

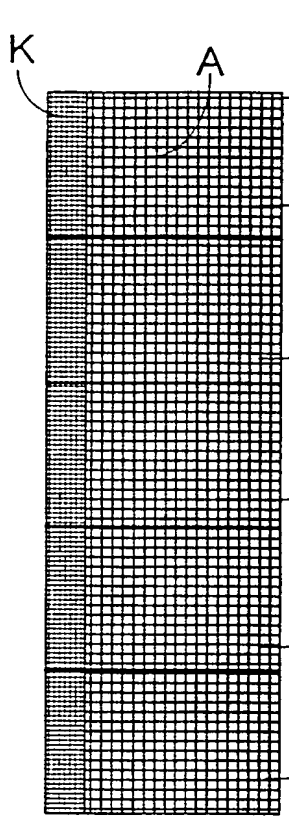

FIG. 2a

2 x N

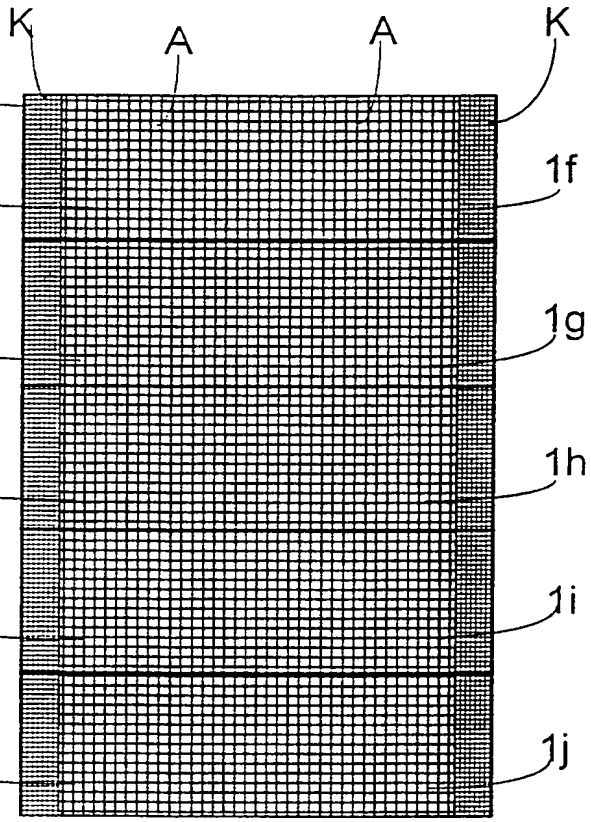

FIG. 2b

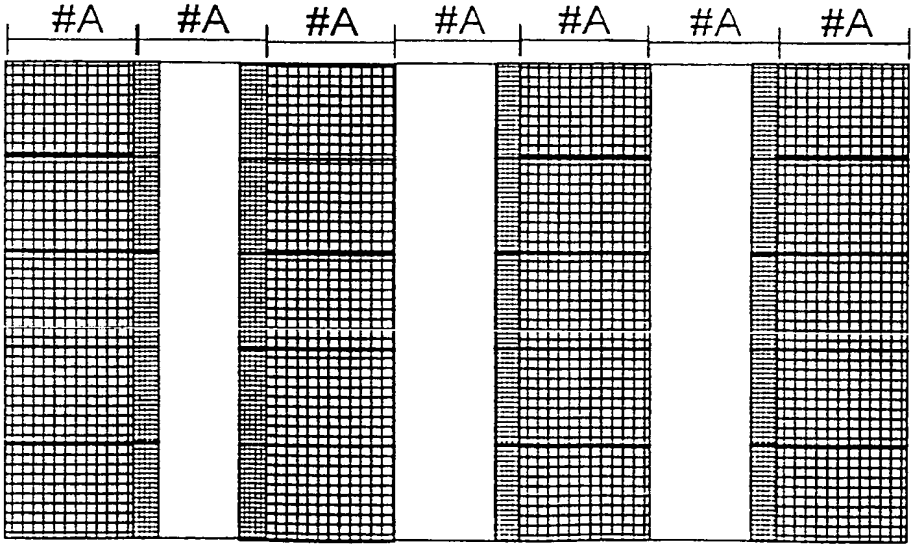

FIG. 3

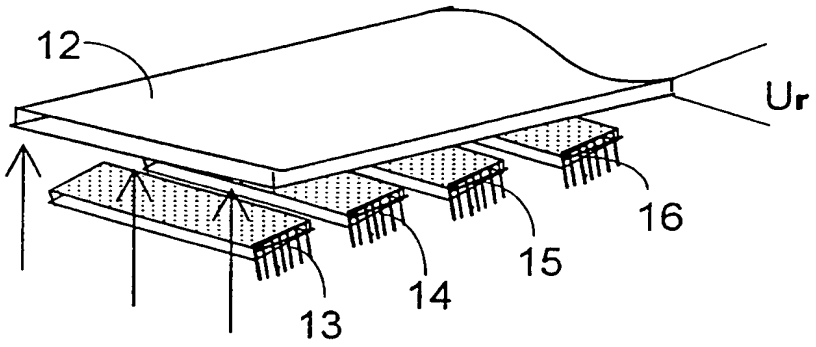

FIG. 4

PCT

REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

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The Finnish Patent Office
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Method and apparatuses for digital imaging

Box No. II APPLICANT

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☒ applicant and inventor

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This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

☐ Further applicants and/or (further) inventors are indicated on a continuation sheet.

Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: ☒ agent ☐ common representative

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

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CONFIRMATION COPY

Box No.V DESIGNATION OF STATES

The following designations are hereby made under Rule 4.9(a) *(mark the applicable check-boxes; at least one must be marked)*:

Regional Patent

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- ☒ **EA** **Eurasian Patent:** **AM** Armenia, **AZ** Azerbaijan, **BY** Belarus, **KG** Kyrgyzstan, **KZ** Kazakhstan, **MD** Republic of Moldova, **RU** Russian Federation, **TJ** Tajikistan, **TM** Turkmenistan, and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT
- ☒ **EP** **European Patent:** **AT** Austria, **BE** Belgium, **CH and LI** Switzerland and Liechtenstein, **CY** Cyprus, **DE** Germany, **DK** Denmark, **ES** Spain, **FI** Finland, **FR** France, **GB** United Kingdom, **GR** Greece, **IE** Ireland, **IT** Italy, **LU** Luxembourg, **MC** Monaco, **NL** Netherlands, **PT** Portugal, **SE** Sweden, and any other State which is a Contracting State of the European Patent Convention and of the PCT
- ☒ **OA** **OAPI Patent:** **BF** Burkina Faso, **BJ** Benin, **CF** Central African Republic, **CG** Congo, **CI** Côte d'Ivoire, **CM** Cameroon, **GA** Gabon, **GN** Guinea, **GW** Guinea-Bissau, **ML** Mali, **MR** Mauritania, **NE** Niger, **SN** Senegal, **TD** Chad, **TG** Togo, and any other State which is a member State of OAPI and a Contracting State of the PCT *(if other kind of protection or treatment desired, specify on dotted line)* .....

National Patent *(if other kind of protection or treatment desired, specify on dotted line)*:

- ☒ **AE** United Arab Emirates
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- ☒ **AM** Armenia
- ☒ **AT** Austria
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- ☒ **CN** China
- ☒ **CU** Cuba
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- ☒ **DE** Germany
- ☒ **DK** Denmark
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- ☒ **ID** Indonesia
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- ☒ **IN** India
- ☒ **IS** Iceland
- ☒ **JP** Japan
- ☒ **KE** Kenya
- ☒ **KG** Kyrgyzstan
- ☒ **KP** Democratic People's Republic of Korea
- ☒ **KR** Republic of Korea
- ☒ **KZ** Kazakhstan
- ☒ **LC** Saint Lucia
- ☒ **LK** Sri Lanka
- ☒ **LR** Liberia
- ☒ **LS** Lesotho
- ☒ **LT** Lithuania
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- ☒ **MD** Republic of Moldova
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Precautionary Designation Statement: In addition to the designations made above, the applicant also makes under Rule 4.9(b) all other designations which would be permitted under the PCT except any designation(s) indicated in the Supplemental Box as being excluded from the scope of this statement. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn bythe applicant at the expiration of that time limit. *(Confirmation of a designation consists of the filing of a notice specifying that designation and the payment of the designation and confirmation fees. Confirmation must reach the receiving Office within the 15-month time limit.)*

Box No. VI PRIORITY CLAIM ☐ Further priority claims are indicated in the Supplemental Box.

Filing date of earlier application (day/month/year)	Number of earlier application	Where earlier application is: national application: country	regional application:* regional Office	international application: receiving Office
item (1) 14 Dec 1998 (14.12.1998)	982704	Finland (FI)		
item (2)				
item (3)				

△RO/FI

☒ The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) *(only if the earlier application was filed with the Office which for the purposes of the present international application is the receiving Office)* identified above as item(s): (1)

** Where the earlier application is an ARIPO application, it is mandatory to indicate in the Supplemental Box at least one country party to the Paris Convention for the Protection of Industrial Property for which that earlier application was filed (Rule 4.10(b)(ii)). See Supplemental Box.*

Box No. VII INTERNATIONAL SEARCHING AUTHORITY

Choice of International Searching Authority (ISA) *(if two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used)*: ISA / SE

Request to use results of earlier search; reference to that search *(if an earlier search has been carried out by or requested from the International Searching Authority)*: Date *(day/month/year)* Number Country *(or regional Office)*

Box No. VIII CHECK LIST; LANGUAGE OF FILING

This international application contains the following **number of sheets**:

request	: 3
description (excluding sequence listing part)	: 12
claims	: 5
abstract	: 1
drawings	: 3
sequence listing part of description	:
Total number of sheets	: 24

This international application is **accompanied by** the item(s) marked below:

1. ☒ fee calculation sheet
2. ☒ separate signed power of attorney
3. ☒ copy of general power of attorney; reference number, if any:
4. ☐ statement explaining lack of signature
5. ☐ priority document(s) identified in Box No. VI as item(s):
6. ☐ translation of international application into (language):
7. ☐ separate indications concerning deposited microorganism or other biological material
8. ☐ nucleotide and/or amino acid sequence listing in computer readable form
9. ☒ other *(specify)*: Copy of Official Action

Figure of the drawings which should accompany the abstract: 1

Language of filing of the international application: Finnish

Box No. IX SIGNATURE OF APPLICANT OR AGENT

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request).

PLANMED OY
Juha Tawast
Corporate Patent Manager

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1. Date of actual receipt of the purported international application: 13 DEC 1999 (13. 12. 99)
2. Drawings: ☐ received: ☐ not received:
3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application:
4. Date of timely receipt of the required corrections under PCT Article 11(2):
5. International Searching Authority (if two or more are competent): ISA / SE
6. ☒ Transmittal of search copy delayed until search fee is paid.

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Date of receipt of the record copy by the International Bureau: 10 JANUARY 2000 (10. 01. 00)

PCT/FI99/01028
10 JAN 2000

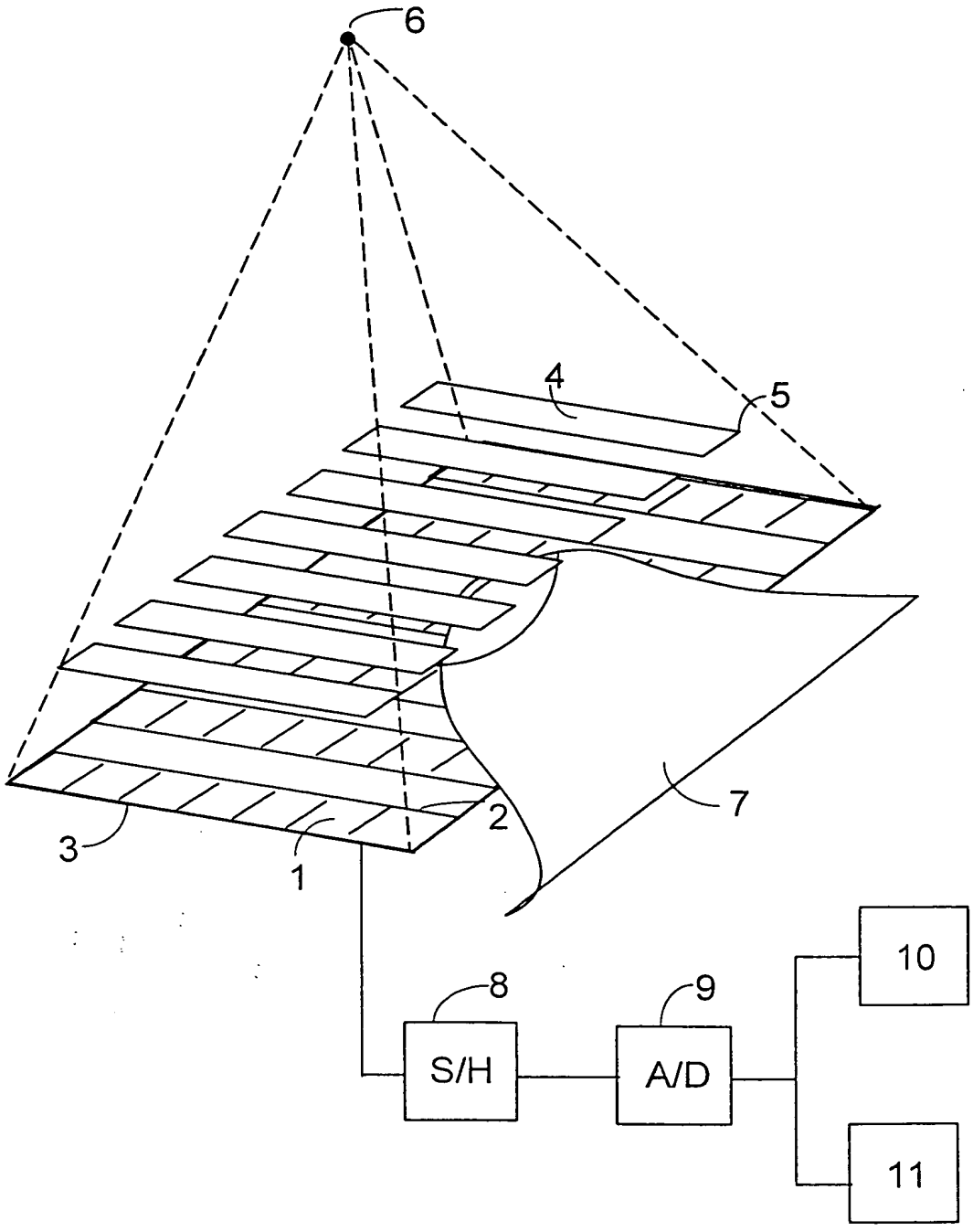

FIG. 1

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1 x N

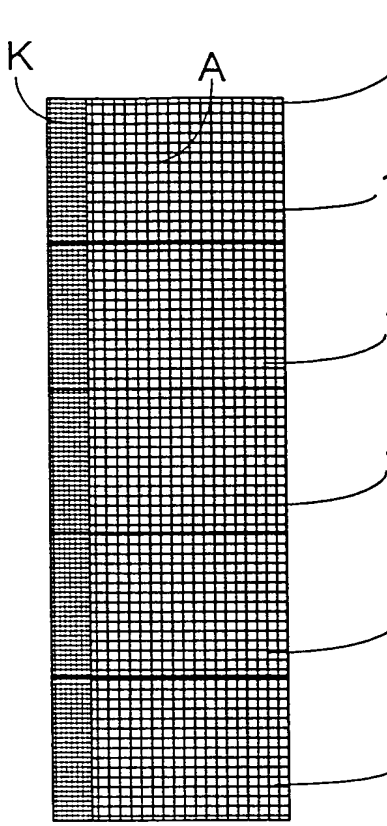

FIG. 2a

2 x N

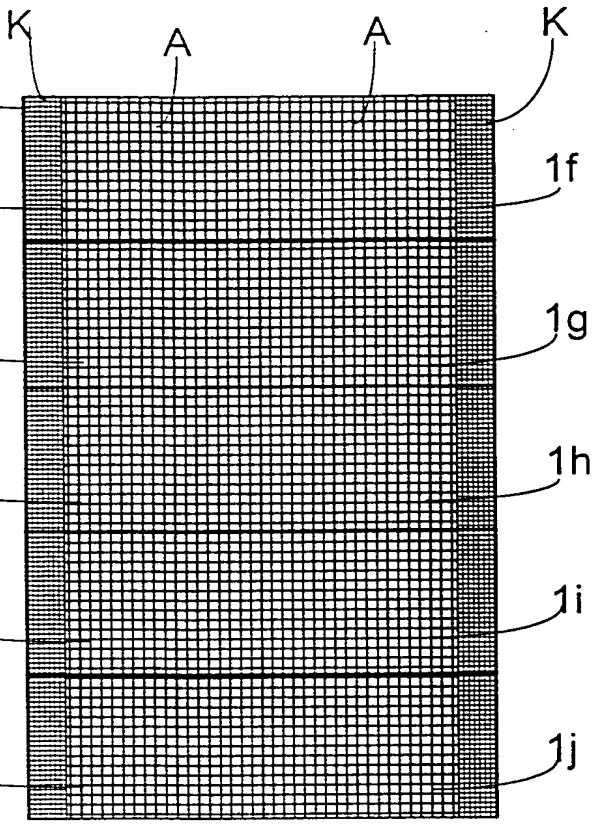

FIG. 2b

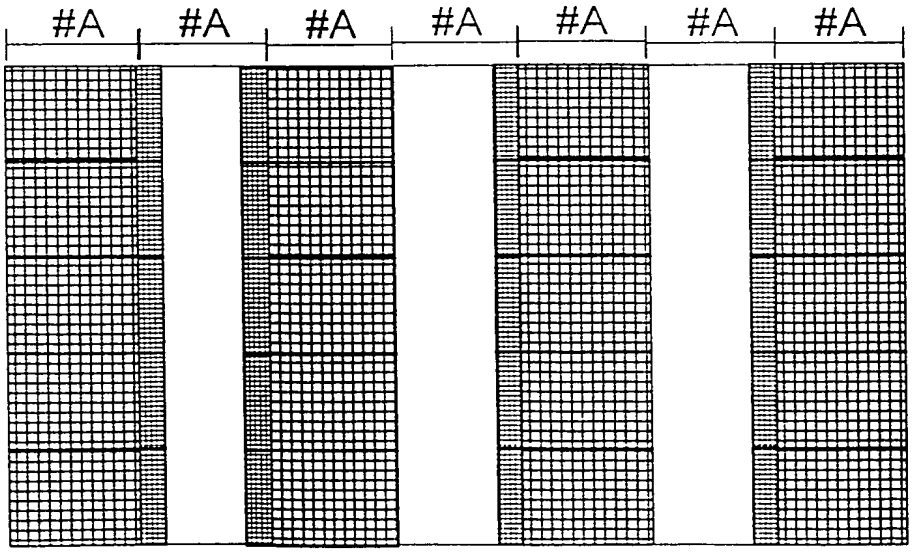

FIG. 3

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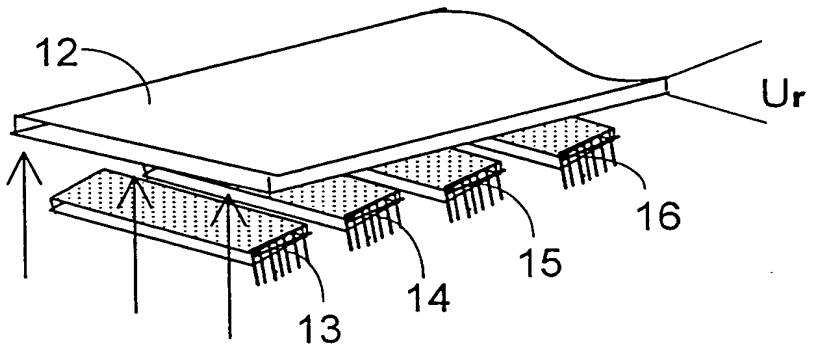

FIG. 4

Digitaalinen kuvantamismenetelmä ja laitteita digitaalisessa kuvantamisessa

Keksinnön kohteena on digitaalinen kuvantamismenetelmä, jossa menetelmässä kuvannettavaa kohdetta säteilytetään ja säteily ilmaistaan puolijohdeantureilla, joiden kattama alue on olennaisesti pienempi kuin kuvanmuodostuspinta.

Edelleen keksinnön kohteena ovat laitteet digitaalisessa kuvantamisessa, jossa kuvantamisessa käytetään säteilylähdettä kuvannettavan kohteen säteilyttämiseksi ja puolijohdeantureita säteilyn ilmaisemiseksi, jolloin puolijohdeantureiden kattama alue on olennaisesti pienempi kuin kuvanmuodostuspinta. Erityisesti keksinnön kohteena on tällaista tekniikkaa soveltava mammografialaite.

Erilaisia kuvantamismenetelmiä käytetään monenlaisissa sovelluksissa. Mm. lääketieteen ja biotekniikan kuvantamissovelluksissa on tyypillistä johtaa kuvannettavan kohteen läpi ja edelleen kuvanmuodostuspinnalle röntgen-, gamma- tai beta-säteilyä. Viime vuosina on perinteisten filmipohjaisten kuvantamismenetelmien rinnalle kehitetty digitaalisia kuvantamismenetelmiä, joissa kuvanmuodostuspintana käytetään puolijohdeantureita, kuten CCD-antureita (Charge-Coupled Device) tai CMOS-antureita (Complementary Metal-Oxide Semiconductor).

Mammografia on tyypillinen lääketieteelliseen tekniikkaan liittyvä digitaalisen kuvantamisen sovellusalue, jossa edellytetään laajaa kuvanmuodostuspintaa, tyypillisesti vähintään kokoa 18 x 24 cm, ja suurta resoluutiota. Mammografiassa asetetaan myös tiukat rajat hyväksyttävälle säteilyaltistukselle. Mammografiakuvaus edellyttää myös kuvanmuodostuspintaa, jonka aktiivinen alue ulottuu kolmelta sivultaan mahdollisimman lähelle kuvantamisalueen ulkoreunaa, jotta rintakehä ja molemmat kainalot voidaan

asettaa kuvausta varten niin, että mahdollisimman paljon kudosta saadaan näkyviin.

Puolijohdeanturit valmistetaan tyypillisesti piistä. Tällaisten anturien yksi haittapuoli on kalleus, sillä anturin koon kasvaessa sen valmistuskustannukset pinta-alaa kohti kasvavat eksponentiaalisesti. Yhden puolijohdeanturin valmistaminen tulee näin erittäin kalliiksi sovellutuksissa, joissa tarvitaan laajaa kuvanmuodostuspintaa.

Edellä kuvattua ongelmaa on yritetty kiertää valmistamalla kuvanmuodostuspinta mosaiikkimaisesti useista pienemmistä puolijohdeantureista, kuten on kuvattu esimerkiksi GB-patenttijulkaisussa 2305096. Tällaisissa ratkaisuissa ongelmaksi muodostuu yhtenäisen kuvanmuodostuspinnan aikaansaaminen, koska suorakaiteen muotoisesta puolijohdeanturista tyypillisesti yksi reuna on varattu ohjauskytkennöille. Tällöin anturien kaikkia reunoja ei voida liittää toisen anturin aktiiviseen alueeseen, vaan niiden väliin jää aina pieni rako. Rakojen aiheuttamien haittojen kompensoimiseksi voidaan käyttää erilaisia linsseihin tai kuituoptiikkaan perustuvia ratkaisuja, mutta linssien haittana on huono hyötysuhde ja kuituoptiikan käyttö aiheuttaa suuria lisäkustannuksia. Joissakin sovelluksissa ongelmaa on yritetty ratkaista valmistamalla laajapintainen anturi amorfiseen piihin perustuvalla puolijohdetekniikalla, mutta tällöin saavutettavissa oleva resoluutio ei riitä suurta tarkkuutta edellyttäviin lääketieteellisiin sovellutuksiin, kuten esimerkiksi mammografiaan.

Eräs tunnettu ratkaisu laajan kuvanmuodostuspinnan aikaansaamiseksi on puolijohdeantureiden järjestäminen shakkilautakuvion omaiseen muotoon riveiksi ja sarakkeiksi siten, että olennaisesti joka toinen shakkilautakuvion ruutu käsittää puolijohdeanturin niin, että yhteen suuntaan, esimerkiksi rivien suuntaisesti antureilla on

ylitystä suhteessa shakkilautakuvion ruutuun ja vastaavasti ortogonaaliseen suuntaan eli sarakkeiden suuntaisesti antureiden väliin jää rako. Tällöin puolijohdeanturiasetelma järjestetään liikkuvaksi siten, että asetelma on siirrettävissä kahdesti suuntaan, jossa antureiden välillä on rako, ja anturiasetelma säteilytetään alkuasennossa sekä molempien asetelman siirtojen jälkeen. Tällöin koko anturiasetelman kattama pinta-ala lukuunottamatta kuvanmuodostuspinnan reunoille jääviä ruutuja saadaan kuvattua kolmella valotuksella.

Ongelmana yllä kuvatussa järjestelyssä on, että anturiasetelma joudutaan siirtämään ja pysäyttämään peräti kolmea eri valotusta varten. Näin kuvantamislaitteen mekaaninen rakenne muodostuu vaikeaksi toteuttaa, useat valotukset kuormittavat säteilylähdettä ja kuvausajasta tulee pitkä.

Liiallisen säteilyaltistuksen välttämiseksi on lääketieteellisissä sovelluksissa usein välttämätöntä kollimoinnin järjestäminen eli säteilyn rajaaminen varjostuksen avulla vain antureiden kullakin hetkellä kattamalle alueelle. Kollimoinnin toteutus muodostaa tällöin oman ongelma-alueensa. Kun esimerkiksi tyypillinen röntgensäteilylähde ei ole pistemäinen vaan sen ulkomitat ovat äärelliset, esimerkiksi luokkaa 0,3 x 0,3 mm, muodostuu laitteiston rakenteesta riippuen kuvannettavan kohteen reuna-alueille muutaman millimetrin levyinen puolivarjon alue, jolla säteily ei ole täysimääräistä. Tämän johdosta kollimointi on suunniteltava siten, että reuna-alueille muodostuu joko ylitystä tai alitusta, ts. että kuvannettavat alueet joko menevät hiukan päällekkäin tai että minkäänlaista päällekkäisyyttä ei synny. Tekniikan tason mukaista shakkilautakuviota käytettäessä ylitys kuitenkin aiheuttaa ristikonmuotoisella alueella säteilyannoksen kaksinkertaistumisen, pisteittäin jopa kolminkertaistumisen kuvan-

nettavassa kohteessa, ja alitus puolestaan muodostuvaan kuvaan ristikonmuotoisen alueen, jossa kuvainformaatiota on vähemmän kuin muualla tai josta se puuttuu kokonaan.

Edelleen ongelman muodostavat kuvanmuodostuspinnan reuna-alueet, joita ei saada kokonaan säteilytettyä. Kuvanmuodostuspinnan reunoille jää tyhjät ruudut, ts. vain joka toisen ruudun alueelta saadaan kuvainformaatiota, jolloin kuvanmuodostuspinnan reunat muodostavat eräänlaisen linnanmuurikuvion.

Keksinnön tavoitteena on kehittää kuvantamismenetelmä ja menetelmää toteuttavia laitteita siten, että yllä mainitut ongelmat saadaan ratkaistua tai ainakin niiden haittoja pienennettyä. Nämä tavoitteet saavutetaan menetelmällä ja laitteilla, joiden tunnusomaiset piirteet on määritelty oheisissa patenttivaatimuksissa, erityisesti itsenäisten vaatimusten tunnusmerkkiosissa.

Erityisesti keksinnön tavoitteet saavutetaan järjestämällä puolijohdeanturit siten, että koko kuvanmuodostuspinta on kuvannettavissa kahdella säteilytyksellä siirtämällä puolijohdeantureita ainoastaan kerran säteilytysten välissä.

Keksinnön yhden edullisen suoritusmuodon mukaan puolijohdeanturit järjestetään olennaisesti suorakaiteen muotoiseksi palkiksi siten, että mainittu palkki käsittää useita puolijohdeantureita, joko yhden tai kaksi sarakkeellista. Edullisesti puolijohdeantureiden ohjaamiseen ja muut tarvittavat kytkennät sijoitetaan tällöin anturin yhdelle sivulle.

Edelleen keksinnön yhden edullisen suoritusmuodon mukaan mainitut palkit järjestetään etäisyyden päähän toisistaan muodostamaan anturimatriisi siten, että etäisyys palkkien

välillä on korkeintaan yhtä suuri kuin mainittujen palkkien puolijohdeantureiden aktiivisen alueen leveys.

Keksintö perustuu puolijohdeanturien järjestämiseen sellaiseen, edullisesti suorakaiteenomaiseen muotoon, että puolijohdeantureita ensimmäisestä asennosta toiseen asentoon siirtämällä ja säteilyttämällä kuvannettava kohde molemmissa asennoissa koko kuvanmuodostuspinta saadaan katetuksi, jolloin nämä kaksi kuvaa yhdistämällä saadaan yhtenäinen kuva koko kuvanmuodostuspinnasta. Kaihdinmatriisin avulla säteily on mahdollista rajata molemmissa asennoissa vain puolijohdeantureiden kattamalle alueelle.

Keksinnön mukaisen menetelmän ja laitteen etuna on helposti toteuttavissa oleva mekaaninen rakenne sekä anturiasetelman että kollimoinnin suhteen. Anturi- ja kaihdinasetelmasta saadaan myös selkeästi kohdistettava ja rakenteeltaan tukeva. Valotuskertojen vähentyessä myös säteilylähteen lämpökuormitus pienenee, minkä ansiosta säteilylähteen jäähdytys ei muodostu merkittäväksi ongelmaksi eikä kuvausten välissä jouduta odottamaan kuvantamistyötä hidastavaa säteilylähteen jäähtymistä. Myös yksittäisen kohteen kuvaamiseen käytettävä aika lyhenee, kun koko kuvanmuodostuspinta saadaan katettua jo kahdella kuvauksella. Edelleen päästään eroon kuvanmuodostuspinnan reunan tyhjistä ruuduista, ts. saadaan suorat kuvanmuodostuspinnan reunat, ja myös edellä kuvatut kollimoinnista aiheutuvat haitat ovat pienempiä kuin tunnetun tekniikan mukaisissa ratkaisuissa.

Keksintöä selostetaan nyt lähemmin sen edullisten suoritusmuotojen avulla ja oheisiin kuvioihin viittaamalla, joista kuvioista

kuvio 1 esittää keksinnön esimerkinomaista toteutusta mammografiakuvauksen yhteydessä,

kuvio 2a esittää yhtä edullista anturipalkin rakennetta,

kuvio 2b esittää toista edullista anturipalkin rakennetta,

kuvio 3 esittää yhtä edullista anturimatriisirakennetta ja

kuvio 4 esittää yhtä edullista anturipalkin muodostustapaa.

Kuviossa 1 keksinnön toteutusta kuvataan esimerkinomaisesti mammografiakuvauksen yhteydessä, mutta luonnollisesti keksintöä voidaan käyttää missä tahansa muussa vastaavassa digitaalisessa kuvantamisessa. Kuvion 1 mukaisesti puolijohdeanturit 1 järjestetään olennaisesti suorakaiteen muotoisiksi anturipalkeiksi 2, joista anturipalkeista 2 muodostuu liikkuva anturimatriisi 3. Anturipalkit 2 järjestetään anturimatriisiin 3 toisiinsa nähden kiinteästi siten, että anturipalkkien 2 väliin jää anturipalkkia 2 kapeampi tyhjä alue. Kollimointi toteutetaan olennaisesti suorakaiteen muotoisilla kaihtimilla 4, jotka puolestaan muodostavat liikkuvan kaihdinmatriisin 5, jossa kaihtimet 4 on asetettu toisiinsa nähden kiinteästi. Kaihdinmatriisi 5 asetetaan kuvausta varten siten, että kaihtimet 4 varjostavat säteilylähteestä 6 katsottuna anturimatriisin 3 anturipalkkien 2 väliset tyhjät alueet, jolloin näille alueille ei kohdistu säteilyä. Kaihdinrakenne voidaan sijoitaa joko kuten kuviossa 1 kuvannettavan kohteen välittömään läheisyyteen tai etäisyyden päähän siitä, jopa aivan säteilylähteen välittömään läheisyyteen. Kuvannettava kohde 7, mammografiassa tyypillisesti rinta, asetetaan kaihdinmatriisin 5 ja anturimatriisin 3 väliin ja koh-detta säteilytetään säteilylähteestä 6 saatavalla säteilyllä. Puolijohdeanturit 1 ilmaisevat vastaanottamansa säteilyn, jonka perusteella muodostetaan digitaalinen kuvainformaatio näytteenotto- ja pitopiirin 8 ja analogia-

digitaalimuuntimen 9 avulla. Kuvainformaatiota voidaan tarvittaessa muokata lisää esimerkiksi pimeävirran ja mahdollisten epälineaarisuuksien kompensoimiseksi. Kuvainformaatio siirretään eteenpäin joko prosessointivälineille 10 tai muistielimelle 11. Tämän jälkeen ja kuvannettavan kohteen 7 pysyessä paikoillaan anturimatriisia 3 siirretään sivuttaissuunnassa siten, että anturipalkit 2 peittävät olennaisesti samat kohdat, missä ennen siirtoa oli anturipalkkien 2 väliset tyhjät kohdat. Tyypillisesti mammografiassa kuvannettava kohde 7 eli rinta pidetään paikallaan puristusvälineiden (ei kuvattu) avulla. Kaihdinmatriisia 5 siirretään vastaavasti siten, että kaihtimet 4 varjostavat nyt anturimatriisin 3 uuden sijainnin mukaiset anturipalkkien 2 väliset tyhjät alueet. Kuvannettava kohde 7 säteilytetään toisen kerran anturimatriisin 3 ja kaihdinmatriisin 5 uusilla asetuksilla, ja ensimmäisen säteilytyksen perusteella muodostettuun kuvainformaatioon yhdistetään toisen säteilytyksen perusteella muodostettava kuvainformaatio prosessointivälineissä 10. Näin kahdella säteilytyksellä saadaan muodostettua kuva koko kuvanmuodostuspinnasta.

Edellä kuvatulla ratkaisulla saavutetaan huomattavia etuja tunnettuun tekniikkaan nähden. Keksinnön mukainen mekaaninen rakenne on helpompi toteuttaa sekä anturimatriisin että kollimoinnin suhteen. Suorakaiteen muotoisista anturipalkeista muodostuva anturimatriisi on selkeästi kohdistettavissa ja se on rakenteeltaan tukeva. Kaihdinmatriisi on myös helppo rakentaa ja se on helposti kohdistettavissa anturimatriisin suhteen. Edelleen kun kuvannettavaa kohdetta säteilytetään vain kahdesti säteilylähteen kuormitus pienenee, mikä pidentää sen käyttöikää ja nopeuttaa kuvantamistatyötä säteilylähteen jäähdytystarpeen pienentyessä, ja myös yksittäisen kohteen kuvantamiseen kuluva aika lyhenee.

Yhtenäiseen kuvanmuodostuspintaan verrattuna keksinnön mukaisessa järjestelyssä tarvitaan vain puolet puolijohdeantureiden aktiivisesta pinta-alasta. Toisaalta esimerkiksi CMOS-antureita käytettäessä keksintö voidaan haluttaessa toteuttaa siten, että minkäänlaisia linsseihin tai kuituoptiikkaan perustuvia järjestelyjä puolijohdeantureiden välisten rakojen kompensoimiseksi ei tarvita.

Kun anturi- ja kaihdinmatriisia siirretään vain kerran, joudutaan huolehtimaan ainoastaan yhteen suuntaan toteutettavan siirron tarkkuudesta. Näin kaihdinmatriisin mtoitus ja kohdistus on mahdollista tehdä siten, että ylitys säteilytettävissä alueissa vähenee merkittävästi ja siten kollimoinnin haitat tunnettuihin ratkaisuihin verrattuna pienenevät.

Digitaalisen kuvan lopullinen muodostaminen voidaan tehdä kytkemällä kuvantamislaitteisto tietokoneeseen, jolloin voidaan hyödyntää tietokoneen muistia ja prosessointivälineitä. Kuvion 1 mukaiset prosessointivälineet 10 voidaan myös toteuttaa esimerkiksi dedikoidulla ACID-piirillä (Application Specific Integrated Circuit), jonka yhteyteen on liitetty muistivälineet 11, esimerkiksi FLASH-muistia. Sinänsä lopullisen kuvainformaation muodostaminen on alan ammattimiehelle tunnettua tekniikkaa eikä sen tarkempi selostaminen ole keksinnön toteutuksen kannalta tarpeen.

Keksinnön yhden edullisen totetutusmuodon mukaan anturimatriisiin 3 asetettavat anturipalkit 2 muodostetaan anturipalkkeja 2 olennaisesti pienemmistä puolijohdeantureista 1. Kuvioissa 2a ja 2b on kuvattu kaksi edullista tapaa järjestää puolijohdeanturit 1 anturipalkiksi 2. Molemmissa kuvioissa anturipalkki 2 käsittää puolijohdeantureita 1a, 1b, . . . , jotka on järjestetty suorakaiteen muotoiseksi anturipalkiksi 2. Tyypillinen puolijohdeanturi 1n käsittää aktiivisen alueen A, jota käytetään vastaanotetun säteilyn

ilmaisemiseen ja kytkentäalueen K, jota kautta välitetään anturin 1n ohjaussignaalit ja varausten purku eli tässä tapauksessa kuvainformaation keruu. Puolijohdeanturissa 1n on tyypillisesti vähintään yksi reuna varattu kytkentäalueelle K, joten puolijohdeanturi 1n voidaan edullisesti liittää toiseen puolijohdeanturiin 1n kolmelta reunalta kuvion 2b mukaisesti, mikäli halutaan antureiden aktiivisten alueiden muodostavan yhtenäisen pinnan. Anturipalkki 2 voidaan näin muodostaa joko yhdestä (1 x N) tai kahdesta (2 x N) sarakkeesta puolijohdeantureita 1n. Anturipalkkien 2 välinen etäisyys anturimatriisissa 3 määräytyy käytettävien puolijohdeantureiden 1 aktiivisen alueen A leveyden #A mukaan, ts. anturipalkkien 2 välinen etäisyys voi maksimissaan olla yhden sarakkeen anturipalkkien 2 tapauksessa A:n leveyden #A verran (kuvio 3) tai kahden sarakkeen anturipalkkien yhteydessä 2 x A:n leveys eli 2 x #A.

Kun anturipalkki 2 muodostetaan olennaisesti anturipalkkia 2 pienemmistä puolijohdeantureista 1n, ei tarvita suurikokoisia ja siten kalliita puolijohdeantureita. Edelleen kustannuksia säästää se, että yksittäisen puolijohdeanturin 1n vioittuessa se voidaan vaihtaa uuteen ilman, että koko anturipalkki 2 jouduttaisiin vaihtamaan.

Kuvio 3 esittää keksinnön mukaista tapaa järjestää anturipalkit 2 edullisesti siten, että kuvanmuodostuspinta muodostuu mahdollisimman suureksi ja kuvanmuodostuspinnan reunat saadaan yhtenäisiksi. Anturipalkit 2 muodostuvat yhdestä sarakkeesta (1 x N) puolijohdeantureita 1n, jolloin uloimmaiset anturipalkit 2 asetetaan siten, että puolijohdeantureiden 1n kytkentäalue K sijoitetaan kohti anturimatriisin 3 sisäpuolta. Tällöin kuvanmuodostuspinta kattaa koko anturimatriisin 3 peittämän alueen eikä ns. linnanmuurikuviota muodostu kuvanmuodostuspinnan reunoille. Anturimatriisin 3 sisäpuolisten anturipalkkien 2

kytkentäalueiden sijoitus voidaan valita vapaasti, kunhan anturipalkkien väliset tyhjät alueet mitoitetaan oikein. Anturipalkit 2 voidaan luonnollisesti muodostaa myös kahdesta sarakkeesta (2 x N) puolijohdeantureita 1n, mutta jos myös reunimmaiset anturipalkit 2 muodostetaan tällä tavoin, ei anturimatriisin 3 aktiivista aluetta saada ulottumaan sivusuunnassa aivan kuvantamispinnan reunoihin asti.

Luonnollisesti keksintöä voidaan myös ajatella sovellettavaksi rakentamalla anturimatriisi, jossa on erilaisia, siis esimerkiksi eri levyisiä aktiivisia alueita omaavia, sekä yksi- että kaksisarakkeisia, vastakkaisilla sivuilla olevia kytkentäalueita omaavia ja/tai jopa eri tekniikkaan perustuvia anturipalkkeja. Kuitenkin ja erityisesti jos tällaisia anturimatriiseja käytetään sovellutuksissa, joissa säteily on rajoitettava anturimatriisin alueelle, saatetaan samalla menettää joitakin keksinnöllä saavutettavissa olevia etuja.

Keksinnön yhden edullisen suoritusmuodon mukaan kaihdinmatriisin ja anturimatriisin liikkeet eivät ole kytkettyjä toisiinsa, vaan kumpaakin matriisia liikutetaan erikseen. Edullisesti tämä tehdään siten, että ensin siirretään anturimatriisi uuteen asemaansa ja sen jälkeen kohdistetaan kaihdinmatriisi anturimatriisin mukaan. Luonnollisesti keksintö voidaan kuitenkin toteuttaa myös siten, että kaihdinmatriisin ja anturimatriisin liikkeet ovat synkronoituja.

Anturien ja/tai kaihtimien liike voidaan toteuttaa esimerkiksi solenoideilla tai erillisillä servomoottoreilla. Erityisesti solenoidin käyttö on suositeltavaa, koska se on halpa, tarkka ja luotettava komponentti. Keksintö nimenomaan mahdollistaa solenoidien käytön, kun sen mukai-

sesti antureita ja/tai kaihtimia tarvitsee siirtää ainoastaan kahden aseman välillä.

Keksinnön yhden edullisen suoritusmuodon mukaan puolijohdeanturit ovat säteilyn suoraan ilmaisuun perustuvia CMOS-antureita, joilla on tiettyjä etuja perinteisiin puolijohdeantureihin nähden. CMOS-antureilla saavutetaan parempi resoluutio kuin perinteisillä puolijohdeantureilla ja rinnakkaisväylätyyppisen tiedonsiirron ansioista ne mahdollistavat kuvainformaation nopeamman siirtämisen. CMOS-teknologia on yleisimmin sovellettava puolijohdeteknologia, minkä ansioista CMOS-piirien saatavuus on hyvä ja niiden valmistuskustannukset pienenevät teknologian kehittyessä.

Kuviossa 4 on kuvattu eräs edullinen tapa muodostaa CMOS-antureista keksinnön mukainen anturipalkki. CMOS-anturit 13, 14, . . . liitetään edullisesti suorakaiteen muotoiseen, olennaisesti palkin ulkomitat käsittävään säteilyn ilmaisimeen 12. Ilmaisin 12 on valmistettu edullisesti seostetusta piistä (Si) tai kadmiumsinkkitelluuriidiyhdisteestä (CdZnTe). Ilmaisimen ylä- ja alapinnan väliin generoidaan biasointijännite U_r, jonka avulla säteilyn synnyttämä virta kerätään lähimmän pikselin kohdalle. Syntyvä virta johdetaan CMOS-antureille 13, 14, . . ., jotka on liitetty ilmaisimeen 12 edullisesti mikroskooppisen pienten pallojohteiden eli ns. pallojuotoksen (bump bonding) avulla. CMOS-antureiden kytkentäalueella, antureiden päässä sijaitsevien liitinnastojen avulla antureille voidaan sekä syöttää kontrollisignaaleja että lukea ilmaistu säteily kuvainformaation muodostamista varten. Säteilyn ilmaisu CMOS-antureiden avulla on alan ammattimiehelle sinänsä tunnettua.

Keksinnön mukaisesti voidaan tietysti käyttää myös sinänsä tunnettuja linssien tai kuituoptiikan käyttöön perustuvia

puolijohdeantureita, jolloin kytkentäalueet on mahdollista sijoittaa anturin kolmiulotteisessa rakenteessa myös sellaiselle pinnalle, että anturin koko leveys saadaan hyödynnetyksi säteilyä ilmaisevana aktiivisena alueena. Tällöin kuitenkin samalla menetetään osa keksinnöllä saavutettavissa olevista eduista.

Vaikka keksintöä on edellä kuvattu esimerkinomaisesti mammografiaan liittyen, voidaan sitä luonnollisesti käyttää myös minkä tahansa muun vastaavan kuvantamissovellutuksen yhteydessä. Keksinnön mukaisesti voidaan käyttää mitä tahansa puolijohdeantureiden ilmaistavissa olevaa säteilyä.

Erityisen hyödyllinen keksintö on lääketieteellisen tekniikan kuvantamissovellutuksissa, joissa tyypillisesti käytetään röntgen- tai gammasäteilyä, ja biotekniikan sovelluksissa, joissa tyypillisesti käytetään betasäteilyä. Edelleen keksintö on sovellettavissa läpivalaisua hyödyntävissä teollisissa testaus- ja laaduntarkastusmenetelmissä.

Alan ammattilaiselle on ilmeistä, että tekniikan kehittyessä keksinnön perusajatus voidaan toteuttaa monin eri tavoin, jolloin sen eri suoritusmuodot eivät rajoitu yllä kuvattuihin esimerkkeihin, vaan ne voivat vaihdella oheisten patenttivaatimusten määrittelemän suojapiirin puitteissa.

Patenttivaatimukset

1. Digitaalinen kuvantamismenetelmä, jossa menetelmässä kuvannettavaa kohdetta säteilytetään ja säteilyä ilmaistaan puolijohdeantureilla, jotka käsittävät aktiivisen alueen ja kolmiulotteisessa rakenteessaan alueen tai alueita ohjauskytkentöjä varten, jolloin puolijohdeanturien kattama alue on olennaisesti pienempi kuin kuvannettavan kohteen kuvanmuodostuspinta, tunnettu siitä, että kuvannettavaa kohdetta säteilytetään kaksi kertaa ja puolijohdeantureita siirretään uuteen asemaan säteilytysten välissä, jolloin anturit järjestetään kattamaan kuvanmuodostuspinta siten, että koko kuvanmuodostuspinta saadaan kuvannetuksi.

2. Patenttivaatimuksen 1 mukainen kuvantamismenetelmä, tunnettu siitä, että puolijohdeanturin kytkentäalue järjestetään sen yhdelle sivulle.

3. Patenttivaatimuksen 1 tai 2 mukainen kuvantamismenetelmä, tunnettu siitä, että puolijohdeanturit järjestetään muodostamaan olennaisesti suorakaiteen muotoinen palkki.

4. Patenttivaatimuksen 3 mukainen kuvantamismenetelmä, tunnettu siitä, että mainittu palkki järjestetään muodostumaan yhdestä sarakkeesta (1 x N) puolijohdeantureita.

5. Patenttivaatimuksen 4 mukainen kuvantamismenetelmä, tunnettu siitä, puolijohdeanturit järjestetään palkissa siten, että niiden kytkentäalueet sijaitevat olennaisesti palkin yhdellä sivulla.

6. Jonkin patenttivaatimuksen 3-6 mukainen kuvantamismenetelmä, tunnettu siitä, että palkeista muodostetaan anturimatiriisi, jolloin palkit järjestetään etäisyyden päähän toisistaan siten, että mainittu etäisyys on

korkeintaan yhtä suuri kuin puolijohdeantureiden palkeissa muodostaman aktiivisen alueen leveys.

7. Patenttivaatimuksen 6 mukainen kuvantamismenetelmä, tunnettu siitä, että anturimatriisin uloimmat palkit järjestetään siten, että niiden aktiivinen alue käsittää kuvanmuodostuspinnan ulkoreunat.

8. Patenttivaatimuksen 3 mukainen kuvantamismenetelmä, tunnettu siitä, että mainittu palkki järjestetään käsittämään kaksi saraketta (2 x N) puolijohdeantureita.

9. Patenttivaatimuksen 8 mukainen kuvantamismenetelmä, tunnettu siitä, että puolijohdeanturit järjestetään palkissa siten, että niiden kytkentäalueet sijaitsevat olennaisesti palkin kahdella sivulla.

10. Patenttivaatimuksen 8 tai 9 mukainen kuvantamismenetelmä, tunnettu siitä, että palkeista muodostetan anturimatiriisi, jolloin palkit järjestetään etäisyyden päähän toisistaan siten, että mainittu etäisyys on korkeintaan yhtä suuri kuin puolijohdeantureiden palkeissa muodostaman aktiivisen alueen leveys.

11. Jonkin patenttivaatimuksen 1-10 mukainen kuvantamismenetelmä, tunnettu siitä, että säteily rajataan olennaisesti anturien kattamalle alueelle, jossa rajaamisessa käytetään edullisesti sopivaa kaihdinrakennetta.

12. Patenttivaatimuksen 11 mukainen kuvantamismenetelmä, tunnettu siitä, että kaihdinrakennetta ja antureita liikutetaan erikseen.

13. Jonkin patenttivaatimuksen 1-12 mukainen kuvantamismenetelmä, tunnettu siitä, että kaihdinrakenteen ja/tai anturien liike toteutetaan solenoidien avulla.

14. Jonkin patenttivaatimuksen 1-13 mukainen kuvantamismenetelmä, tunnettu siitä, että puolijohdeantureina käytetään CMOS-antureita.

15. Jonkin patenttivaatimuksen 1-14 mukainen kuvantamismenetelmä, tunnettu siitä, että menetelmää käytetään mammografiakuvauksen yhteydessä.

16. Laite digitaalisessa kuvantamisessa, jossa kuvantamisessa käytetään säteilylähdettä kuvannettavan kohteen säteilyttämiseksi ja puolijohdeantureita säteilyn ilmaisemiseksi, jolloin puolijohdeanturit (1) käsittävät aktiivisen alueen (A) ja kolmiulotteisessa rakenteessaan alueen tai alueita ohjauskytkentöjä varten (K) ja joiden puolijohdeantureiden (1) kattama alue on olennaisesti pienempi kuin kuvanmuodostuspinta, tunnettu siitä, että laitteeseen kuuluu välineet siirtämään puolijohdeantureita (1) uuteen asemaan kahden säteilytyksen välissä, jolloin puolijohdeanturit (1) ja välineet niiden siirtämiseksi on järjestetty siten, että puolijohdeantureiden (1) kattama alue alkuasemassaan yhdistettynä puolijohdeantureiden (1) kattamaan alueeseen siirretyssä asemassaan kattavat koko kuvanmuodostuspinnan.

17. Patenttivaatimuksen 16 mukainen laite, tunnettu siitä, että puolijohdeanturin (1) kytkentäalue (K) on järjestetty sen yhdelle sivulle.

18. Patenttivaatimuksen 16 tai 17 mukainen laite, tunnettu siitä, että useasta puolijohdeanturista (1n) on järjestetty muodostumaan olennaisesti suorakaiteen muotoinen palkki (2).

19. Patenttivaatimuksen 18 mukainen laite, tunnettu siitä, että mainittu palkki (2) käsittää yhden sarakkeen (1 x N) puolijohdeantureita (1n).

20. Patenttivaatimuksen 19 mukainen laite, tunnettu siitä, puolijohdeanturit (1n) on järjestetty palkissa (2) siten, että niiden kytkentäalueet (K) sijaitsevat olennaisesti palkin (2) yhdellä sivulla.

21. Jonkin patenttivaatimuksen 18-20 mukainen laite, tunnettu siitä, että palkit (2) muodostavat anturimatriisin (3), jossa palkit (2) sijaitsevat etäisyyden (A#) päässä toisistaan siten, että mainittu etäisyys (A#) on korkeintaan yhtä suuri kuin puolijohdeantureiden (1n) mainituissa palkeissa (2) muodostaman aktiivisen alueen (A) leveys.

22. Patenttivaatimuksen 21 mukainen laite, tunnettu siitä, että anturimatriisin (3) uloimpien palkkien (2) aktiivinen alue (A) käsittää kuvanmuodostuspinnan ulkoreunat.

23. Patenttivaatimuksen 18 mukainen laite, tunnettu siitä, että mainittu palkki (2) käsittää kaksi saraketta (2 x N) puolijohdeantureita (1n).

24. Patenttivaatimuksen 23 mukainen laite, tunnettu siitä, että puolijohdeanturit (1n) on järjestetty palkissa (2) siten, että niiden kytkentäalueet (K) sijaitsevat olennaisesti palkin (2) kahdella sivulla.

25. Patenttivaatimuksen 23 tai 24 mukainen laite, tunnettu siitä, että mainitut palkit (2) muodostavat anturimatiriisin (3), jossa palkit (2) sijaitsevat etäisyyden (A#) päässä toisistaan siten, että mainittu etäisyys (A#) on korkeintaan yhtä suuri kuin puolijohdeantureiden (1n) mainituissa palkeissa (2) muodostaman aktiivisen alueen (A) leveys.

26. Jonkin patenttivaatimuksen 16-25 mukainen laite, tunnettu siitä, että siihen kuuluu välineet säteilyn rajaamiseksi olennaisesti anturien (1) kattamalle alueelle, jotka välineet käsittävät edullisesti sopivan kaihdinrakenteen (4, 5).

27. Patenttivaatimuksen 26 mukainen laite, tunnettu siitä, että siinä on erilliset välineet yhtäältä kaihdinrakenteen (4, 5) ja toisaalta anturien (1) liikuttamiseksi.

28. Jonkin patenttivaatimuksen 16-27 mukainen laite, tunnettu siitä, että mainitut välineet kaihtimien (4, 5) ja/tai anturien (1) liikuttamiseksi käsittävät solenoidin.

29. Jonkin patenttivaatimuksen 16 - 28 mukainen laite, tunnettu siitä, että puolijohdeanturit (1) ovat CMOS-antureita.

30. Mammografialaitteisto, johon kuuluu minkä tahansa vaatimuksen 16-29 mukainen laite kuvannettavan kudoksen digitaaliseksi kuvantamiseksi.

(57) Tiivistelmä

Digitaalinen kuvantamismenetelmä, jossa kuvannettavaa kohdetta säteilytetään ja säteily ilmaistaan puolijohdeantureilla (1), joiden kattama alue on pienempi kuin kuvanmuodostuspinta. Puolijohdeanturit (1) järjestetään siten, että kuvanmuodostuspinta voidaan kuvata kahdella säteilytyksellä siirtämällä puolijohdeantureita (1) säteilytysten välissä. Säteily voidaan rajata antureiden (1) kattamalle alalle kaihtimin (4). Puolijohdeanturit (1) järjestetään edullisesti suorakaiteen muotoisiksi palkeiksi (2), jotka käsittävät useita puolijohdeantureita (1) yhden tai kahden sarakkeen muodossa, jolloin palkit (2) järjestetään edullisesti etäisyyden päähän toisistaan, joka etäisyys on korkeintaan yhtä suuri kuin palkkien puolijohdeantureiden aktiivisen alueen leveys.

(Kuvio 1)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 99/01028

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H04N 3/15, H04N 5/325
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5572037 A (HONG LIU ET AL), 5 November 1996 (05.11.96), see whole document	1-30
A	US 4245158 A (PAUL BURSTEIN ET AL), 13 January 1981 (13.01.81), see whole document	1-30
A	GB 2186149 A (DR. JOHN GORDON RUSHBROOKE ET AL), 5 August 1987 (05.08.87), see whole document	1-30
A	WO 95/15072 A1 (FISCHER IMAGING CORPORATION), 1 June 1995 (01.06.95), see whole document	1-30

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
9 June 2000	16 -06- 2000
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer JESPER BERGSTRAND/EE Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 99/01028

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0854644 A2 (SIMAGE OY), 22 July 1998 (22.07.98), see whole document -- US 5150394 A (ANDREW KARELLAS), 22 Sept 1992 (22.09.92), see whole document -- --------	1-30 1-30

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/12/99

International application No.
PCT/FI 99/01028

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5572037 A	05/11/96	AU 4914596 A	21/08/96
		WO 9624047 A	08/08/96
US 4245158 A	13/01/81	NONE	
GB 2186149 A	05/08/87	NONE	
WO 95/15072 A1	01/06/95	NONE	
EP 0854644 A2	22/07/98	EP 0853427 A	15/07/98
		EP 0854639 A	22/07/98
		EP 0854643 A	22/07/98
		AT 172343 T	15/10/98
		AU 691926 B	28/05/98
		AU 2672095 A	21/12/95
		CA 2191100 A	07/12/95
		DE 69505375 D,T	08/04/99
		EP 0763302 A,B	19/03/97
		SE 0763302 T3	
		ES 2123991 T	16/01/99
		FI 964728 A	02/12/96
		GB 2289979 A	06/12/95
		GB 2289980 A	06/12/95
		GB 2289981 A	06/12/95
		GB 2289983 A,B	06/12/95
		GB 9410973 D	00/00/00
		GB 9421289 D	00/00/00
		GB 9502419 D	00/00/00
		GB 9508294 D	00/00/00
		GB 9605294 D	00/00/00
		IL 113921 A	15/04/97
		JP 10505469 T	26/05/98
		NO 965104 A	03/02/97
		NZ 287868 A	24/04/97
		US 5812191 A	22/09/98
		WO 9533332 A	07/12/95
		EP 0787335 A	06/08/97
		JP 10507137 T	14/07/98
US 5150394 A	22/09/92	US 5465284 A	07/11/95
		WO 9109495 A	27/06/91

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Assistant Commissioner for Patents
United States Patent and Trademark Office
Box PCT
Washington, D.C.20231
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 14 September 2000 (14.09.00)	
International application No. PCT/FI99/01028	**Applicant's or agent's file reference**
International filing date (day/month/year) 13 December 1999 (13.12.99)	**Priority date** (day/month/year) 14 December 1998 (14.12.98)
Applicant NYHOLM, Kustaa	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

29 June 2000 (29.06.00)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer Nestor Santesso
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

Copy for the elected Office (EO/US)

09/866051

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

COMMUNICATION IN CASES FOR WHICH NO OTHER FORM IS APPLICABLE

To:

TAWAST, Juha
Planmed Oy
Asentajankatu 6
FIN-00810 Helsinki
FINLANDE

Date of mailing (*day/month/year*)	
24 August 2001 (24.08.01)	
Applicant's or agent's file reference	**REPLY DUE** see paragraph 1 below
International application No. PCT/FI99/01028	International filing date (*day/month/year*) 13 December 1999 (13.12.99)
Applicant PLANMED OY	

1. ☐ REPLY DUE within _____ months/days from the above date of mailing

☐ NO REPLY DUE, however, see below

☒ IMPORTANT COMMUNICATION

☐ INFORMATION ONLY

2. COMMUNICATION:

The International Bureau regrets to inform the applicant that, due to a clerical error in the international publication, Claims 21 to 30 are missing from the published pamphlet WO 00/36820 of 22 June 2000 (22.06.00).

Therefore, a correction of the pamphlet containing the missing claims will be published in due course.

The International Bureau (WO) regrets any inconvenience caused.

A copy of this letter has been sent to the receiving Office (RO/FI) and all the designated Offices concerned.

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. (41-22) 740.14.35

Authorized officer
Beatriz LARGO

Telephone No. (41-22) 338.83.38

PATENT COOPERATION TREATY

PCT

REC'D 23 MAR 2001
PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

14

Applicant's or agent's file reference ----	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/FI99/01028	International filing date *(day month year)* 13.12.1999	Priority date *(day month year)* 14.12.1998
International Patent Classification (IPC) or national classification and IPC7 H04N 3/15, H04N 5/325		
Applicant Planmed Oy et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 4 sheets, including this cover sheet.

☐ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of _____ sheets.

3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
- III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- IV ☐ Lack of unity of invention
- V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI ☐ Certain documents cited
- VII ☐ Certain defects in the international application
- VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
29.06.2000	14.03.2001
Name and mailing address of the IPEA/SE Patent- och registreringsverket Box 5055 S-102 42 STOCKHOLM Telex 17970 PATOREG-S Facsimile No. 08-667 72 88	Authorized officer Jesper Bergstrand/LR Telephone No. 08-782 25 00

Form PCT/IPEA/409 (cover sheet) (January 1998)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/FI99/01028

I. Basis of the report

1. With regard to the **elements** of the international application:*

☒ the international application as originally filed

☐ the description:
pages _____, as originally filed
pages _____, filed with the demand
pages _____, filed with the letter of _____

☐ the claims:
pages _____, as originally filed
pages _____, as amended (together with any statement) under article 19
pages _____, filed with the demand
pages _____, filed with the letter of _____

☐ the drawings:
pages _____, as originally filed
pages _____, filed with the demand
pages _____, filed with the letter of _____

☐ the sequence listing part of the description:
pages _____, as originally filed
pages _____, filed with the demand
pages _____, filed with the letter of _____

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language english which is:

☐ the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).

☒ the language of publication of the international application (under Rule 48.3(b)).

☐ the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

☐ contained in the international application in written form.

☐ filed together with the international application in computer readable form.

☐ furnished subsequently to this Authority in written form.

☐ furnished subsequently to this Authority in computer readable form.

☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. ☐ The amendments have resulted in the cancellation of:

☐ the description, pages _____

☐ the claims, Nos. _____

☐ the drawings, sheet/fig _____

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2 (c)).**

* *Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*

** *Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.*

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-30	YES
	Claims		NO
Inventive step (IS)	Claims	1-30	YES
	Claims		NO
Industrial applicability (IA)	Claims	1-30	YES
	Claims		NO

2. Citations and explanations (Rule 70.7)

The claimed invention relates to a digital imaging method whereby semiconductor sensors, covering an area smaller than the image-forming surface, are used for detection. The sensors are moved to new positions between irradiations, so that the entire image-forming surface can be imaged in two irradiations.

The following documents are cited in the International Search Report:

D1: US 5572037 A
D2: US 4245158 A
D3: GB 2186149 A
D4: WO 9515072 A
D5: EP 0854644 A
D6: US 5150394 A

Document D1 relates to a scanning-type digital imaging apparatus for generating large area images with high resolution. The method according to this document is similar to the method according to the invention. However, the invention according to claim 1 differs from document D1 in respect to moving the semiconductor sensors between irradiations and irradiating the object only twice. This may be important because frequent exposures place a load on the radiation source and the imaging time is thus prolonged. Therefore, the invention according to claim 1 is considered to be novel and may also be considered to involve an inventive step.

The above stated arguments are also applicable to the invention according to claim 16.

Document D2 describes the general state of the art and relates to a soft x-ray spectrometric imaging system. .../...

Supplemental Box
(To be used when the space in any of the preceding boxes is not sufficient)

Continuation of: V

Document D3 defines the general state of the art and relates to image differencing using masked CCD for an X-ray system, including a masked region, which comprises a storage zone into which charge patterns from unmasked pixels may be transferred by fast parallel shifting.

Document D4 describes prior art and relates to a digital scan mammography system.

Documents D5 and D6 also describe prior art. However, none of the documents D1-D6 are considered to be of particular relevance.